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# PLASTICS
# IN INDUSTRY

*By* “PLASTES

*With Thirty-two Plates*

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# LIST OF PLATES

## LIST OF PLATES AND DIAGRAMS



## LIST OF DIAGRAMS IN TEXT

# INTRODUCTION

THIS book has been compiled in order that it may be read by the industrialists of the world. The writers hope, with due modesty, that by such reading many confused ideas regarding plastics and the plastics industry will be clarified and that there will be presented to the eyes of the aforesaid industrialists a comparatively new series of materials of construction worthy of their examination and, finally, worthy of their employment for series or mass production. There is, indeed, much that is puzzling in an industry that can produce at will such diverse objects as radio cabinets, milk bottles, bearings for metal rolling-mills, coffins, bottle caps, aeroplane parts and life-size cast statues.

The present century is one of intense scientific development. But it is also productive, on occasion, of considerable loose thinking and sensationalism: with the result that we have had thrust upon us by the ubiquitous journalist the idea that this is the Plastics Age, conveying some division of history equivalent to the Stone Age or Bronze Age, and that ships and shoes and sealing wax and imitation cabbages and kings' crowns are all made of plastics. As well call this the Age of Concrete or Dyestuffs or Textiles merely because considerable quantities are used. Such talk is foolish, and it often becomes dangerous, as when the journalist announces to the world the discovery of a new chemical substance and adds or infers that, since it is made from abundant raw materials, it must necessarily be cheap. A synthetic substance may be cheap. On the other hand, it may be very expensive.

To take an example. The daily papers have announced to the world that synthetic rubber is made from acetylene and that since carbide from which acetylene is made is a penny or so per pound, therefore the motor-cars of the world will soon be running on synthetic tyres that cost next to nothing. This is a distortion of the present facts, for synthetic rubber is being sold at about 4*s.* per lb. and will probably never (certainly not in the next twenty-

five years) reach a price equal to that of natural rubber, say 8*d.* to 1*s.* per lb. The manufacture of synthetic rubber entails a large number of very complicated expensive chemical steps, comprising the use of intricate and expensive plant and supervision. Moreover, as a raw material for tyre making it is little, if at all, superior to natural rubber—it finds an important place at its high price for *other* purposes where it is superior to rubber in certain ways. For example, rubber dissolves or swells badly in certain oils and so cannot be used for making pipes and valves for carrying such oils. Synthetic rubber is not affected by many oils, so that we have here a new material of construction of great value to the industrialist for a purpose that natural rubber cannot satisfy and which is, in fact, worth the 4*s.* per lb. that he pays.

The urgent thing to realise is that one should not regard prime cost as a prime consideration. It is the character or suitability of the material for definite purposes that should first be examined, when sundry advantages may be discovered—and real low cost re-found.

The secret with regard to plastics lies first in the fact that they are easily moulded into complicated shapes and secondly they possess many properties presenting outstanding advantages for many purposes.

The manufacturers of the world must realise the following few facts illustrated by one particular type of plastic :

An object, when made from metal, may have to be built up from several separate pieces, the very making of which can entail a waste of 20–50 per cent. of metal. In the building it is crimped, soldered, screwed or welded, sand-blasted and degreased, chromium-plated or painted ; varnished, buffed or polished before it can be sold to the customer. A simple metal object may undergo a dozen processes of preparation. The same object in plastics, polished and coloured throughout, can be turned out one, two or a dozen at a time in two minutes with virtually no waste of raw material, and only needing packing to be ready for the customer. Moreover, plastics often allow of simpler designs. We leave the industrialist to imagine what economic value this may have on his business. A plastic material at 1*s.* per lb. can sometimes be cheaper than sheet steel at 2*d.* per lb.

Because of the characteristics and properties of plastics the telephone has been transformed from a metal horror to a shape

of considerable æsthetic value and supreme mechanical and electrical merit ; the motor-car has been lightened in weight, made safer, more colourful and probably less costly ; machinery has been fitted with silent gears and bearings that outlast the toughest phosphor bronzes ; art has been enriched by new materials for fashioning ; social life has been completely changed by the introduction of a vast range of articles of domestic utility of low price and considerable beauty that has greatly accelerated the spending tendencies of the masses.

But there is more in this book, the writers hope, than mere enthusiasm for plastics because they are new materials. They hope to give a real picture, too, of the limitations of plastics—this they believe is necessary to the well-being of the industry.

When the strength or hardness or weight of steel is essential, plastics cannot be employed. When an electrical conductor or heat conductor is required, plastics, again, cannot be used. When great sizes in one piece are required, plastics cannot be used, for, at present, there are limits to the size of moulds or size of the raw material (if in sheet form) that can be obtained. Mere size may eventually and probably will be overcome, other properties may be improved, others cannot be changed. The plastics industry does not offer a panacea for all ills, nor a constructional material for all purposes.

If the writers succeed in their object of giving the reader a true picture of plastics, they have every hope that the world will thereby be enriched.

## CHAPTER I

# DEFINITIONS AND THE PLASTICS INDUSTRY

WHAT is the plastics industry and what are the materials it deals with ? There is considerable confusion in the mind of the general public and even many technically trained. This lack of understanding is not due to any absence of intelligence on the part of enquirers, but rather because of the necessity for sound definitions within the plastics industry itself.

Let us try and explain the general difficulty by beginning with a theoretical definition of plastics.

A plastic material is one that, under pressure, will change its shape and, on release of that pressure, will retain its new shape.

But this definition is obviously too wide for our purpose, since it includes putty or clay and even steel and most metals.

The real clue is given by the statement that the plastics industry manufactures rigid or semi-rigid units of construction of considerable mechanical strength, made from plastic organic materials exclusively and not metallic or mineral compounds. Where a metallic or mineral compound does become an ingredient it is merely as a filler for the main organic binder, so as to give the latter special properties.

In other words, the word " plastics " is governed not by any theoretical physico-chemical definition, but by the very practical limits of the output of a branch of engineering—the plastics industry. Plastics are defined by the history of the plastics industry.

We may consider that the industry really began with the introduction of celluloid (about 1875), casein (1905) and bitumen. The last two named were, at the beginning of the twentieth century, enjoying the doubtful privilege of being called " composition "—a name which meant little but was given to almost anything that was of an indeterminate character and not made from metal, wood or stone.

Celluloid was used to make combs, dolls, toys, collars and knife handles from moulded celluloid by one or two firms in the great industrial countries, Germany, Great Britain, U.S.A. and Japan. When casein came on the scene, it could be worked in almost the same way and was made into very similar articles—combs, buttons, knife handles, fountain pens, billiard balls, etc. Often the celluloid factories also made casein plastics, and with the passing of time they became expert in the moulding of such materials. The extrusion of casein powders and the shaping of celluloid rod and sheet became a purely engineering job.

Bitumen and asphalt tell another story. When the electrical industry expanded, as the result of ambitious schemes of electrification throughout the country, there arose a demand for insulating materials other than ebonite and mica. Coal tar residues and petroleum asphalts were found to give very good results, especially when mixed with asbestos, silica dust, etc., and, moreover, were found to be amenable to shaping under pressure and low heat into rigid insulators of all types. Yet another fillip was given to this type of "composition" when the motor-car industry needed a rigid box to contain acid and so become an accumulator box. All these insulators and boxes were moulded in steel dies under pressure, and, here again, with the passage of time, the concerns that undertook bitumen moulding became very expert at the job, and this, in turn, like the celluloid and casein industry, assumed the aspect of engineering industries.

When Bakelite, the first phenol-formaldehyde synthetic resin, was first introduced, it was found to be an excellent insulator and, moreover, mouldable into useful and complicated shapes. Quick recognition of the potentialities of Bakelite was made by the electrical industries using bitumen and ebonite dust. It was soon realised that the new synthetic resins were readily adaptable to the moulding technique with heated dies. It was the logical sequence of events. When these works expanded, new ideas or, rather, new applications came in abundance from the outside world—ash trays, switch covers, cigarette boxes, telephone receivers, and a thousand other articles. The simple moulders of celluloid toys or bitumen insulators were able to undertake the manufacture of very complicated mouldings for almost any industry, light or heavy.

To-day the plastics industry has at least a dozen chemically

different raw materials, all organic in character, at its disposal and all mouldable under heat and pressure.

It may be argued that rubber is a true plastic. This is so, but the fact remains that the rubber industry, even though it is a moulding industry, is not considered to be in the plastic industry for purely economic reasons—it is a self-contained industry, does not employ the same high-pressure moulding machinery (except in the case of tube or rod extrusion) and does not utilise synthetic resins as a raw material. The plastics industry, in its turn, does not mould tyres and, in fact, does not use rubber as a raw material.

On the other hand, synthetic rubber is considered to be in both industries—obviously in the case of the rubber industry and in the plastics industry because many rubber-like synthetic materials are utilised by certain plastic moulders.

Similarly, a section difficult of definition is the rayon industry. This cannot be considered to be of the plastics industry since textiles form an enormous industry on their own. Yet the raw materials, viscose or cellulose acetate, are used also as film and sheet, and the manufacturer and shaper of such material is considered to be in the plastics industry.

The segregation is noted in the technical journals on plastics which generally omit mention of natural rubber and textiles.

It may be taken then that the plastics industry is one that in a variety of engineering processes, high-pressure moulding, injection moulding, extrusion into rods or tubes, shaping or forming of sheet, impregnation of paper, fabric and wood, utilises a range of organic substances, largely synthetic, among which the following are best known:

Celluloid.
Cellulose acetate.
Casein.
Bitumen.
Phenol-formaldehyde resins.
Urea-formaldehyde resins.
Soya bean phenol-formaldehyde resins.
Acrylic resins.
Vinyl resins.
Polystyrenes.
Synthetic rubber.

## CHAPTER II

# THERMO-PLASTIC AND THERMO-SETTING RESINS

## CHIEF PLASTICS—THEIR MANUFACTURE AND PROPERTIES

BEFORE proceeding to the main argument of this book, the industrial applications of plastics, it is advisable and indeed necessary to obtain some insight of their source, their manufacture and properties and, finally, the manner in which they are processed by moulding and other means into the final forms in which they appear on the market.

This insight of raw material manufacture is advisable, not merely because it is a fascinating subject, but also because it is necessary to an understanding of the after-processing adopted and of the reasons for choosing certain plastics for certain purposes.

Nevertheless, the industrial applications of plastics and their portrayal to the potential industrial user and commercial trader is the chief function of this book. And since it is not a chemical or physical treatise on plastics, the methods of manufacture are described but very generally, shortly, and, as far as possible, in a non-technical manner. To those who seek pure chemical knowledge of the subject there are many text-books available.

As we have already stated in the opening chapter, the modern plastics under discussion are organic compounds which are distinguished from metallic or other inorganic substances by being derived from carbon. Organic substances are typified by all living or dead carbonaceous matter: coal, flesh, wood and other plant life, petroleum, fats, etc. They also include a host of synthetic, semi-synthetic or derived compounds obtained by chemical processes from the aforementioned natural organic raw materials. Among synthetic materials are dyestuffs, explosives,

fuels, pharmaceutical products, solvents, etc. To these we now add the raw materials of the comparatively new plastics industry.

To the economic geographer the study of plastics is interesting, since, given that plastics production is as nationally important as we believe it to be, we have only to indicate those countries which possess (*a*) primarily an abundance of coal and/or petroleum and, secondarily, wood, cotton, etc., and (*b*) the technical skill and machines to process them, as being those which fortune will favour especially in this new industrial effort.

Plastics are so varied in composition that it is desirable, for the sake of clarity, to divide them into sections. The method adopted here is quite general and relates to two broad divisions dependent on a simple physical distinction. This distinction finds its echo in the methods of processing the two divisions.

1. Those which are softened, moulded or shaped by pressure, with or without heat, *and whose finished hardened shape can be re-softened by heat and re-moulded.*

   Such plastics are the heat-softening type and are generally called *thermo-plastics.*
2. Those which, in their original condition, flow and can be moulded by heat and pressure, but which, once in their finished shape or " cured " condition, *cannot be re-softened or re-moulded.* This final moulded shape remains rigid and hard when heated.

   Such plastics are the heat-hardening type and are generally called *thermo-setting plastics.*

The best known under each of these divisions are—

| *Thermo-plastics.* | *Thermo-setting Plastics.* |
|---|---|
| Cellulose compounds. | Phenol-formaldehyde resins. |
| Bitumen. | Soya-phenol-formaldehyde resin. |
| Casein. | Urea-formaldehyde resins. |
| " Styrene " resins. | Melamine-formaldehyde resins. |
| " Vinyl " resins. | |
| " Acrylic " resins. | |
| Synthetic rubbers. | |

## THERMO-PLASTICS

### Cellulose Plastics.

These comprise a fairly wide range of materials made from cellulosic materials, such as cotton, paper, wood, etc., by interaction with chemicals.

**Cellulose Nitrate,** better known as *Celluloid*, is the oldest of the plastics, having been discovered by an Englishman, Alexander Parkes, in 1864. He did not concern himself with its commercial application, but some ten years later its manufacture began in the great industrial countries, Great Britain and U.S.A., and later in Germany and France.

**Manufacture.**—Purified cotton linters are stirred with a mixture of nitric and sulphuric acids. The cellulose of the cotton combines with the nitric acid forming cellulose nitrate with the liberation of water which is absorbed by the sulphuric acid. The resulting cellulose nitrate pulp, after removal of excess acid, is stabilised by boiling with water and separated in a centrifuge. At this stage the cellulose nitrate still retains its " cottony " or fibrous form. To produce from this celluloid plastic, it is first treated with alcohol and then kneaded with camphor, rolled and calendered into sheets ; consolidation of a number of sheets under pressure results in the production of solid blocks. Without the addition of dyes or pigments, celluloid is nearly water white and transparent, but by such addition it can be made coloured and transparent, coloured and opaque or of variegated colours at will.

**Forms of Celluloid.**—From these solid blocks, large sheets from $\frac{4}{1000}$ in. in thickness upwards can be produced by slicing-machines. Celluloid also appears on the market in the form of rods and tubes.

Most readers will have handled celluloid in some form or other and are therefore able to visualise most of its properties. Apart from other reasons it is described first, so that comparisons with other similar plastics will be easier.

### Properties and Uses of Celluloid.

1. High inflammability.
2. Ease of moulding.

3. Tensile strength, about $2\frac{1}{2}$–5 tons per sq. in.
4. High impact strength, 0·3–1·0.
5. Water absorption, 1–3 per cent. by weight in twenty-four hours' immersion.

The first property immediately limits the uses of celluloid to those where contact with fire is extremely unlikely. It is thus confined, or should be confined, to fancy goods for the dressing-table and bathroom and to objects such as fountain-pens, cycle pumps and mudguards, knife handles and ping-pong balls. Cinematograph film is almost always made from celluloid, and large numbers of children's dolls are also fabricated therefrom. Some blame has been laid at the door of manufacturers for producing dolls of this material. While we have no desire to minimise any danger that exists, it must be pointed out that casualties are few, and there appears to be far more danger in crossing a road. Nevertheless, it is to be hoped that all such dolls will be replaced one day by non-inflammable material.

**Cellulose Acetate.**

Chemically, cellulose acetate has been known almost as long as celluloid, but it was not until about 1914 that manufacture assumed reasonable proportions; it was then used not as a mouldable plastic, but as a dope for producing lacquers for aircraft. It was not until 1924 that sheet and, later, moulding powders became known to the market. The great attractiveness of acetate lies in the fact that it is non-inflammable, compared with celluloid, and perfectly safe. Otherwise, in appearance, strength and mouldability there is little to choose between the two materials.

**Manufacture.**—Cellulose acetate is manufactured in a manner closely resembling that of celluloid. The chief raw material is cellulose, and since cotton is the purest form of cellulose it is almost always employed. Some success has been obtained by using other forms of cellulose, e.g. wood pulp and even straw, but especial purifying methods must be adopted, otherwise the quality of the finished cellulose acetate is affected.

Cellulose is treated with acetic acid and a derivative of acetic acid called acetic anhydride. The acetate resulting from this reaction is in a syrupy form, from which a white powdery or

flaky material is obtained. This is then dissolved in a mixer with organic solvents and plasticisers, and a plastic dough is obtained containing 50 per cent. or more of cellulose acetate. This dough is then rolled on hot rollers to reduce the volatile solvents and used to make sheets, tubes, rods or moulding powder. For the production of tubes and rods the dough is extruded directly. Sheets are made by the slicing of solid blocks (up to 8 in. thick), obtained by consolidating the rolled dough in hydraulic presses and then cooling.

**Properties.**—In appearance, feel, hardness, toughness, etc., there is little difference between celluloid and cellulose acetate. The main properties of cellulose acetate are—

1. Specific gravity = 1·27.
2. Non-inflammability.
3. Tensile strength, 3–5 tons per sq. in.
4. Impact strength $\left\{\begin{array}{l}\text{sheet, about } 0{\cdot}3\text{–}0{\cdot}5 \\ \text{moulded, about } 0{\cdot}9\text{–}1{\cdot}5\end{array}\right\}$.
5. Water resistance, 1–3 per cent. in twenty-four hours.

The low water resistance is a drawback, but occasional contact with water has no effect on cellulose acetate. The general excellent properties allow the material to be very widely used. It does not yellow like cellulose nitrate and, consequently, has replaced the latter in many directions. It possesses high resistance to petroleum, vegetable oils, dilute acids and alkalis.

It is produced in sheet form for safety-glass, aircraft and decorative industries and is available in Great Britain in the following sizes: 55 × 24 in. and 50 × 16 in. and from $\frac{4}{1000}$ to about $\frac{1}{2}$ in. thick. Rods can be supplied in 52-in. lengths and $2\frac{1}{4}$-in. diameter.

In addition to the sheet form, moulding powders have become available in the last ten years and have been employed in ever-increasing quantities with the introduction of the new technique of injection moulding. All forms are available in transparent, translucent or opaque colours.

## Regenerated Cellulose—Viscose.

This is not normally considered a plastic since by far the greatest proportion goes to the textile industry as the fibre rayon.

But enough quantities of film as well as bottle caps are made from viscose to warrant its inclusion here.

**Manufacture.**—Viscose differs from cellulose nitrate and acetate by the fact that the finished product is not a combination with another chemical compound (e.g. nitric acid or acetic) but remains cellulose. The change is the loss of the original fibrous structure without any great change in the molecule.

The raw material is cellulose—generally wood pulp or paper. Treatment with caustic soda followed by carbon bisulphide and then again with soda results in the production of a viscous liquid. For the production of rayon the fluid is squeezed through a spinneret, a metal disc containing numerous tiny holes, and the extruded fine fibre hardened in an acid bath.

Viscose film (it is best known on the market under the trade name of "Cellophane") is produced by spreading viscose dope on rollers.

### Casein.

One of the oldest plastics in industry is casein, which is derived from milk. It is one of the protein plastics and, although of little or no application in the heavy industry, it enjoys great popularity in the fancy-goods trade, where its cheapness and the beauty of its finished texture make it attractive. The finished sheet or rod is known as imitation horn and can be made to resemble tortoiseshell very closely.

**Manufacture.**—The earliest developments took place probably about the year 1897 by a German chemist, named Spitteler, working for a firm desirous of producing a material for making white boards for school work. Skimmed milk is treated with rennet and the precipitated casein is washed and dried, the pure casein resembling a granulated powder. In order to make a plastic material from this, it is mixed with a little water to swell it, pigments, dyestuffs and certain softening or plasticising chemicals. The resulting mixture is not a paste, but a damp powder. This powder is then expressed through a high-pressure extruding machine to form solid rods or, alternatively, through the machine fitted with a mandrel if tubes are required. Sheets are made by packing a number of rods together between two sheets of metal and subjecting them to pressure in a "daylight" press. Rods, sheets and tubes are then placed for prolonged periods in

tanks containing formaldehyde solution in order to harden and stabilise them.

**Properties and Uses.**

| | |
|---|---|
| Tensile strength | 7,000–8,000 lb. per sq. in. |
| Water absorption | 5–7 per cent. by weight in twenty-four hours' immersion. |

Casein plastics are quite strong, but the great drawback is their high water absorption, thus limiting their applications. Even so, some small use is made of them in electrical work for low-tension parts.

By far the greatest quantities are employed in the fancy goods trade. It may be pointed out here that the casein-working trade does not use moulding plant. Its raw materials are the rods, tubes and sheet described above, which it fashions by sawing, drilling, turning, grinding and polishing, to which processes the raw material readily lends itself. Fountain pens, "tortoiseshell" objects, ladies' buttons, umbrella handles, combs, knitting needles and dress buckles are thus produced. (Men's buttons, on the contrary, are made from corozo or ivory nut, a much cheaper raw material.)

**Bitumen.**

Bitumen, asphalt, pitches and similar materials form a small yet important branch of the plastics industry, being employed in the electrical industry where cheapness, backed by reasonably good dielectric strength, is important. The important point to realise about these compositions is that not only are they thermoplastic, but they are actually moulded in cold moulds. They were originally conceived to provide a material for electrical construction as an addition to ebonite, mica and porcelain, and although the electrical properties are well below these, yet they serve admirably for many purposes.

The composition is generally made up by melting bitumen and mixing with asbestos and silica dust. The hot mixture resembles dough or putty and while in this condition is placed in a cold mould, when it is pressed into the desired shape. On cooling the moulded shape is hard and reasonably strong. Terminal blocks, panels, transmission parts, and overhead line insulators are widely produced for the electrical industry, and battery

boxes and accumulator cases for the motor-car industry : bitumen mouldings are very resistant to sulphuric acid :

| | |
|---|---|
| Tensile strength . . . | about 1,100 lb. per sq. in. |
| Cross break strength . . | ,, 3,000 ,, ,, ,, ,, |

**Polymerised Thermo-Plastics.**

All the previously discussed thermo-plastics are derived directly from natural materials, cotton, wood, bitumen, milk, etc. They were all known and used prior to 1914, some of them being well established, as we have already indicated, for over forty and sixty years.

Within the last ten to fifteen years there has been added to this section of the industry a large number of synthetic compounds, that is, substances built up by purely chemical means from very simple chemicals. They have assumed great importance to the plastics industry, because of their manifold advantages over the older type.

At this point it will be interesting to indicate some of the important differences between celluloid or cellulose acetate and these new synthetic thermo-plastics.

In the manufacture of celluloid or cellulose acetate we begin with the large, heavy and complicated molecule of cellulose and we obtain a union between this and a very small nitric acid or acetic acid molecule. The new celluloid or acetate molecule is only very slightly larger in weight or size than the original cellulose molecule. It has changed slightly in chemical character, so that we are now able to dissolve the new cellulose form in special solvents, in which cotton would not dissolve, to make a plastic.

With the new thermo-plastics we are about to describe we begin with a very simple organic substance of small molecular size and weight. By special processes we are able to make a large number of these small similar molecules join or coalesce to form one very large molecule. By such a method from a simple liquid we can make a solid. This process is called polymerisation and the resulting product is called a polymer.

We may portray the difference in production between, say, celluloid (cellulose nitrate) and any polymer by the following diagrams. (They are, of course, neither chemically nor physically correct, but merely serve to indicate the difference in the type of reaction.)

**Cellulose Nitrate :**

| | | | | |
|---|---|---|---|---|
| One molecule of cellulose | unites with | one molecule of nitric acid | to form | one molecule of cellulose nitrate. |

**Polymer :**

O + O + O + O + O . . . . = OOOOO. . . . .

| | | |
|---|---|---|
| Many molecules of the same chemical compound | "coalesce" to form | one molecule of a polymer. |

In actual practice many hundreds of small molecules may be made to form one molecule of a polymer.

The following new plastics are among the polymers :

## Polystyrene.

To make this we begin with a simple well-known liquid called styrene, made from benzene. Styrene is a colourless, odorous liquid boiling at 150° C., but on heating under carefully controlled conditions it polymerises and changes to the solid polymer, called polystyrene. It is probable that in this change several hundreds, or even thousands of molecules of the original liquid styrene coalesce to form one molecule of the new solid polystyrene.

**Properties.**—Polystyrene comes on the market as a snow-white powder, which in the mould is compressed to form a transparent substance outwardly resembling cellulose acetate. It possesses, however, certain properties which render it an outstanding plastic in many fields :

| | |
|---|---|
| Specific gravity . . . . | 1·05 |
| Tensile strength . . . . | 2½–3 tons per sq. in. |
| Compression strength . . | 7 ,, ,, ,, ,, |
| Impact strength . . . . | 0·2 |
| Power factor . . . . | 0·0001 |
| Breakdown voltage (50 cycles) | 500–700 volts per mil. |
| Water absorption (24 hours) | nil |

Its impact strength is somewhat less than cellulose acetate, that is, it is more brittle, but its great resistance to water and its excellent electrical properties make it an admirable material for high-frequency television equipment and transmission cables.

In Britain it has been almost solely used for electrical purposes,

Crude methyl methacrylate polymer ready for drying process.

(*Courtesy : E. T. Du Pont de Nemours.*)

*Facing p.* 13.]

but in Germany it replaces cellulose acetate in many applications, since cellulose plastics are not made from indigenous materials. Thus boxes, bottle caps, toys, etc., of polystyrene are quite common in Germany. Although a high-priced material, its low specific gravity and suitability for high-speed production lower final costs considerably.

**" Acrylic " Resin.**

When about the year 1935 this new type of resin first appeared on the market, it was received with acclaim because of its amazing optical properties and, consequently, because of its great possibilities in fields that could not be entered by any other plastics. Indeed, optically, it is clearer than glass and it also possesses the strange property of being able to transmit light through its curved forms. It thus assumed a great importance as an organic " glass."

**Manufacture.** The best known of the " acrylic " resins is chemically described as poly-methylmethacrylate—a derivative of acrylic acid. The raw material for its manufacture is coal, from which ethylene is obtained. This gas is treated with acid to form ethylenechlorhydrin, from which is produced acrylic acid and, thence, methylmethacrylate. This liquid is then polymerised to the solid resin.

**Properties.**

| | |
|---|---|
| Specific gravity | about 1·2 |
| Water absorption (7 days) | 0·25 |
| Tensile strength (lb. per sq. in.) | 10,000 lb. |
| Dielectric strength (volts per mil.) | 300 |

This polymer is produced as cast sheet or cast rod, or in a powder form suitable for moulding by compression or injection moulding.

The sheet, in which form the resin is most widely used, can be manipulated in exactly the same manner as cellulose acetate sheet: that is, by warming to about 100° C. it can be formed to desirable shapes, its largest outlet being the making of transparent gun-turrets, windscreens, etc., for aircraft. For these purposes the resin is extremely valuable because of its stability at very low temperature.

One of the most important outlets for this material which

first attracted industrialists is the optical industry. We refer to this work in a more appropriate chapter.

"Acrylic" resin, too, lends itself admirably to manipulation by the artist, for not only can beautiful effects be obtained from it by turning and surface grinding, but its forming properties in rod, tube or sheet enable it to be made into lovely transparent shapes. Artists in the United States especially, have rapidly adopted it for producing furniture.

A word should be added here regarding the moulding powder variety. This is not, in fact, a powder, but a form made up of very tiny perfectly spherical shapes of the order of $\frac{1}{100}$ in. in diameter. It is probable that some use will be made of this, as such, by a spraying process, depositing the spheres on a suitably receptive surface to make a special type of reflector. In Great Britain the powder is widely used for moulding special units such as telephone receivers, because of the low water absorption of the finished moulding, good electrical properties, its beauty and good strength.

## POLYVINYL CHLORIDE AND POLYVINYL ACETATE RESINS

The last four or five years have seen the phenomenal growth of these compounds, which are made with acetylene or natural gas or "cracked" petroleum gases as a starting-point, converted into vinyl chloride and vinyl acetate, both of which are liquids, and then by polymerisation changed to solid plastics.

Much of the earlier work was carried out in Canada and U.S.A. (principally on polyvinyl acetate) and in Germany and Great Britain (principally on polyvinyl chlorides), and although large quantities of the separate plastics are made and employed, mixtures of both are becoming of widespread importance. These mixtures are not mechanical mixtures of the separate polyvinyl acetate and polyvinyl chloride. The liquid vinyl acetate and chloride are first mixed together and then polymerised.

There is a considerable range of these plastics depending on the extent of the polymerisation, which varies from the coalescence of about 75 to 250 molecules to form one molecule of the solid. The lower the polymerisation the softer and more rubber-like the plastic; the higher the polymerisation the harder and stiffer the final polymer.

Thus some of these remarkable plastics are of rubber or

linoleum texture, while others are harder than a very hard wood :

| | |
|---|---|
| Specific gravity . . | about 1·35 |
| Tensile strength . . | 4–5 tons per sq. in. |
| Impact strength . . | up to 0·6 |
| Water absorption . . | 0·1 (twenty-four hours' immersion) |
| Breakdown voltage (60 cycles) | 650 volts per mil. |

Their resistance to chemical action, including oxidation, low water absorption, toughness, excellent electrical properties and range of flexibility made a great appeal to the electrical industry, where their use as cable-sheathing is now widespread. One U.S.A. concern states that between 1937 and 1939 it has produced 50,000,000 yards of such cable.

More recently polyvinyl plastics have been employed as floor-cloth, long-playing phonograph records, tubes for conveying water and beer, etc., storage batteries, and as covering for cloth.

They are available in sheet, tube and moulding powder form.

**Polybutylenes.**

In this section must be mentioned an interesting series of thermo-plastics which resemble the polyvinyls closely. The polybutylenes, made from a gas called isobutylene which is extracted from "cracked" petroleum gases, have been produced in Germany and the U.S.A. One of this type on the market is sold in the form of foil and is extremely stable to acids and alkalis. It has been suggested for the lining of acid storage tanks, for making wooden containers water-tight and as an intermediate layer to prevent the passage of water through brickwork. Furthermore, it has been advocated for roof joints and the lining of guttering. Polybutylenes are also available in paste form and so employed by German railways to impregnate wagon sheets, thus replacing linseed oil. It is also stated that these compounds are exceptionally resistant to mustard gas.

## POLYETHYLENE

This is one of the newest polymers and, although no exact information is available, seems to be confined in manufacture to Great Britain.

It appears to be one of the simplest of all polymers, since it is

made from the direct polymerisation of the very simple gas ethylene obtained from coal. Again a wide range is possible. In texture they resemble the polyvinyl plastics, and it is even claimed by some that they possess even better electrical properties.

Sheet, tubes and tape forms are available and, in addition to electrical applications, one form is admirably suited for the making of bottle closures, since they can be made not only colourful but are easily moulded and, what is very important, do not need a liner. They are self-sealing on the bottle rim.

## NYLON

The most recent and perhaps promising plastic so far discovered has just appeared (1940) as a marketable product.

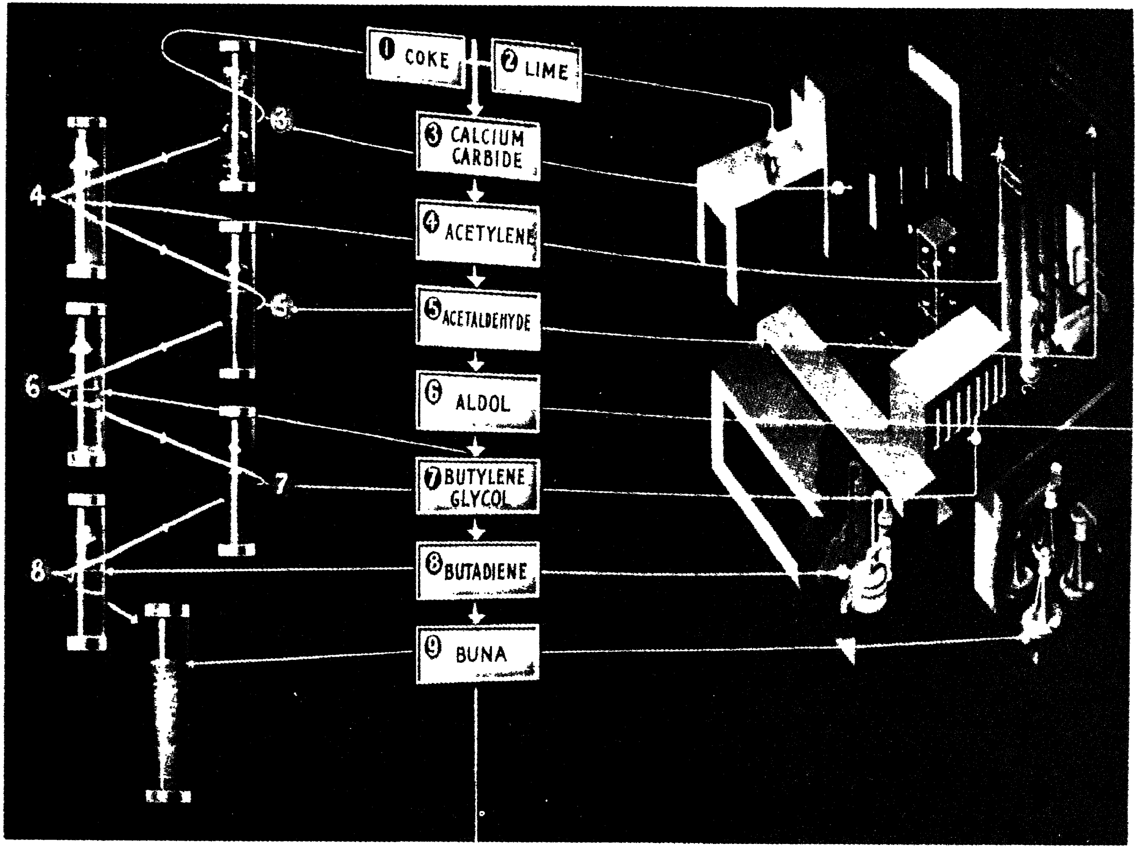
It had long been prognosticated that the strongest plastic would be of a polymerised protein nature. How true this is for nylon is not quite clear, but it appears to be much stronger than any other yet made.

The industrial research on this material has been carried out by E.I. du Pont de Nemours Inc. of U.S.A. and seems to have followed the classical work of Emil Fischer of Germany, who attempted to produce proteins from simple amino-acids. By reacting certain organic acids with amino compounds and then polymerising the products the chemists of du Pont's have succeeded in making a series of plastics now termed nylon.

In one form nylon is produced as a thread admirably suited, because of its strength, for the production of stockings equal to the best silk stockings, fishing lines, and even tooth-brush bristles. Tooth-brush bristles have now made their appearance in England, where manufacture of nylon is being carried out. They are stated to be much more resistant to rubbing than the natural bristle and each bristle is perfect in form and colour when it is extended. The elaborate processes of picking, cleaning, and disinfection are avoided.

## SYNTHETIC RUBBERS

The name " synthetic rubber " should rightly be applied only to those synthetic materials whose molecules resemble very closely those of natural rubber. There are a number of these, but in addition there are also some synthetic compounds whose molecules differ materially from the natural rubber molecule, but which are




Diagrammatic illustration of the synthesis of Buna synthetic rubber (Paris Exhibition 1937).

[Facing p. 16.

here included for convenience, since they are very " rubbery " in appearance and properties.

The search for synthetic rubber has been carried out not merely for purely scientific reasons, but also because it has long been realised that imports from the rubber-growing countries may be stopped or impeded during war-time.

Once rubber had been analysed and had been broken down by heat into the liquid isoprene, attempts were made to synthesise or build up the rubber molecule by starting from isoprene or allied substances, such as butadiene. It is noteworthy that in 1910 two British chemists, Matthews and Strange, patented a process for polymerising these compounds to form synthetic rubber, and a company was formed in England about 1914 to exploit the process. However, no synthetic rubber was produced on a commercial scale and the work was discontinued after 1918.

During the same period similar work was being carried out in Germany, and although the synthetic rubbers produced during the war of 1914–18 were of a very poor quality, yet the German chemical factory so far persisted in their efforts as to reach, ultimately, complete success. To-day the Buna synthetic rubbers are world-famous. As will be seen from the accompanying diagram, the raw materials are simply coke and lime and thence via acetylene to butadiene, which is finally polymerised by metallic sodium to Buna rubber. Similar work had been going on in Russia, and it is believed that modern Russian synthetic rubbers closely resemble Buna rubber.

Production in the U.S.A. is noteworthy for the manufacture of neoprene, which, although originating from acetylene, is obtained by treating a derivative of acetylene with hydrochloric acid and producing a colourless liquid, chloroprene, boiling at 60° C. This, on polymerisation, gives the synthetic rubber called neoprene.

Among the synthetic rubbers must be included Thiokol, although there is little resemblance between its molecules and those of natural rubber. It is obtained by the interaction between certain chlorinated hydrocarbons and metallic polysulphides.

All the synthetic rubbers are produced in sheet form, but, in addition, thiokol is available as a moulding powder.

**Properties.**—The most significant fact about the synthetic rubbers is that they are better in physical properties than natural

rubber and have entered special sections of the industrial market at prices much higher than rubber. Their most valuable property is high resistance to petrol and other oils, which allows it to capture those markets which natural rubber fails to satisfy. Their applications in industry are discussed in another chapter.

## ANILINE-FORMALDEHYDE RESINS

Thermo-plastic resins of considerable promise have been made in Switzerland and Germany from aniline (the well-known dyestuffs intermediate) and formaldehyde. Units made from the material are exceptionally water-repellent and are stable under heat over 100° C. Although not widely known in Great Britain, one concern at least is employing it here for special electrical purposes :

| | |
|---|---|
| Specific gravity . . . . | 1·25 |
| Tensile strength . . . . | 4½ tons per sq. in. |
| Compressive strength . . . | 9 ,, ,, ,, ,, |
| Water absorption (24 hrs.) . . | 0·01 per cent. |
| Breakdown voltage (60 cycles, volts per mil.) . . . . . . | > 600 |
| Power factor ($10^6$ cycles) . . | 0·006 |

## THERMO-SETTING PLASTICS

These synthetic compounds are more widely known to the public than any other plastic compound, because of widespread publicity and the fact that so many general utility objects made from them reach the average home. As often as not they are all termed by the generic name of bakelite, although this name is a trade name belonging to the Bakelite Corporation of America and to Bakelite Ltd. of Great Britain. There are now many manufacturers of similar plastics, but the name of Bakelite will always be remembered as the first of a very remarkable series of synthetic plastics—the phenol-formaldehyde type.

The thermo-setting type of synthetic resins are generally divided into two sections :

(*a*) Phenol-formaldehyde resin type. These comprise resins made from pure phenol (carbolic acid) and other phenolic bodies also extracted from coal tar.

(*b*) Urea-formaldehyde synthetic resins. These comprise those made from urea itself or other organic compounds which, like urea, contain an " amino " or ammonia group.

**Phenol-Formaldehyde Resins.**

Leo Baekeland, an American of Belgian origin, was probably the first to produce a synthetic resin with marketable possibilities. This took place in 1909. The search had been carried out by many others too, with the object of replacing the natural resins imported from abroad and which were generally impure and uncertain in character. His researches pursued a trend that had been begun as early as 1872, namely the formation of resin-like products by the interaction of phenolic compounds and formaldehyde. Thus, the first commercial synthetic resins were produced and given the name of Bakelite in America. In England, about 1914–16, the Damard Lacquer Co. was working on the same lines.

**Manufacture.**—As their names imply, the phenol-formaldehyde synthetic resins are made by the interaction of phenol (carbolic acid) and formaldehyde under carefully controlled heating conditions. Other phenolic bodies such as cresylic acid are also employed. The phenol is obtained by the distillation of coal tar or from benzene (also obtained from coal tar), while the formaldehyde is obtained either from wood distillation or from coal by synthetic means. Both liquids mix readily to form a clear liquid mixture, but, on heating, union of the molecules takes place with the separation of water, and a layer which is viscous when hot but solid and resinous when cooled by pouring into large trays. It is this solid resin which has changed the face of many industries.

It must be remembered that in this condition, as drawn and cooled from the stills, the resin is in what is called a first stage : that is, it can be melted or dissolved in alcohol or oil, and it is not until the final stage under high temperature and pressure that it changes to its final condition of infusibility and insolubility found in the finished moulded object.

To return to the first-stage resin. From this are prepared the raw materials for several sections of the industry :

1. Moulding powders by mixture with fillers.

2. Resin impregnation of paper or fabric—laminated material.
3. Castings for further working by lathe, drilling, grinding, etc.
4. Solutions in drying oils for the paint and varnish industry. This section is outside the scope of this book.

**Moulding Powders.**—For moulding operations the pure first-stage resin is never used alone, but is ground, mixed with fillers to a plastic condition and, when cooled, re-ground to a fine mesh. By varying the type of filler (which may be as much as 50 per cent. of the finished powder) different properties are conferred on the finished moulding. Thus, wood flour, asbestos, mica, cotton flock and other fabrics, in addition to pigments, are employed.

Wood flour is employed for what are called "General Purpose" moulding powders; these give very satisfactory results for many purposes and are the cheapest type. The other fillers are used to give increased heat resistance, exceptionally high electrical properties, great strength, especially impact strength, moisture or acid or alkali resistance, and so on. The properties of some of the mouldings made from different mixtures are given in the chapter entitled "Specifications."

There are literally dozens of different phenolic powders made by each of the great manufacturing concerns to suit the demands of the different buying industries. What is most important is that the scientific control of the manufacture has happily reached such a high pitch that consistent quality as to both physical and chemical properties is general. This is reflected in the fact that these powders are by far the widest used of all plastics and the use is growing at a rapid rate.

## Cast Phenolic Resins.

In addition to the foregoing methods of transforming the half-stage liquid resin into moulding powders, etc., one of the most interesting is the production of transparent solid forms by the very simple process of casting it without fillers.

**Manufacture.**—The phenolic synthetic resin employed for casting is not produced in exactly the same way as that described for resin for moulding powder manufacture. During the produc-

tion of the latter, water separates from the resin and is removed by vacuum. The latest methods adopted for cast resin manufacture result in resin that still contains a small proportion of water. But the size of the particles of this contained water can be so regulated that the final cured resin can be made either perfectly transparent, because of extremely small particles of water, or perfectly opaque when the particles are larger. Intermediate-sized particles provide translucency. The addition of colours produce lovely effects.

**Casting.**—The hot half-stage resin in syrupy form is poured into lead, glass, or rubber moulds, which are placed in heated ovens maintained at 75°–80° C. for considerable periods. Forty-eight hours or more are generally required to transform the half-stage soluble resin to its final infusible, insoluble form.

The chief advantage in casting resins is the fact that lead, glass, or rubber moulds are simply and cheaply constructed, and where lead moulds are employed they can be re-melted and the lead re-used. In the moulding of resin powders, extremely accurately machined and costly moulds of special steels are necessary. Thus, for the production of a cast resin rod a simple lead tube closed at one end is made. This rod, when finally hardened, is removed from the mould and on slicing, drilling, otherwise machined, and finally polished, can be made into buttons, imitation jewellery, shaving-brush handles, etc. Similarly, using slightly more complicated moulds, tubes and rods of various cross-section or profile, box-shapes, blocks, sheets, and even two-colour castings can be secured to make toys, table-napkin rings, letterings for display purposes, and radio cabinets.

The most sensational mouldings of cast resin were seen at the New York Fair in 1939, where there were displayed a number of more than life-size transparent figures illuminated from within. These were each about 10 ft. in height and weighed $\frac{2}{3}$ ton. Made in glass they would have weighed some $1\frac{1}{2}$ tons. In spite of their glass-like appearance, the castings are extremely strong.

**Properties.**

| | |
|---|---|
| Specific gravity | 1·27 |
| Tensile strength | 3–4 tons per sq. in. |
| Cross break strength | 5–8 ,, ,, ,, ,, |

More recently cast resins have been produced in Germany by

Dr. Raschig that are considerably stronger, and in view of the simplicity of producing structures, are now employed in chemical engineering as acid-resisting tubes for conveying acids, acid-pump housings, etc.

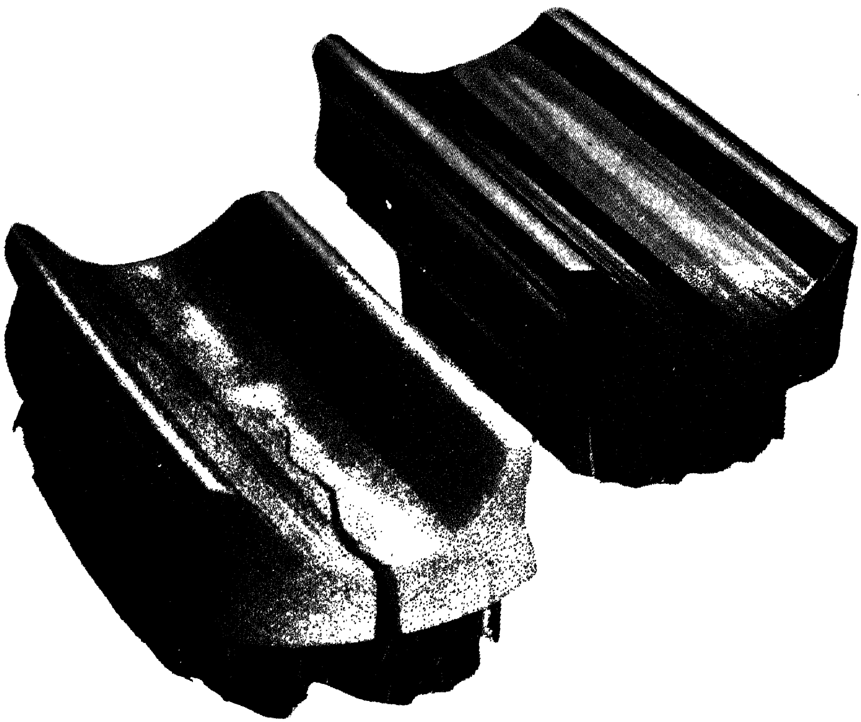
Some indication of the durability of cast resins may be gathered from the following simple, but practical, tests carried out on two nail-brushes. The accompanying photograph shows them in actual size. That on the left is a brilliant red-coloured brush that has been in more or less continuous use for two years and nine months. Twice a day after use it was allowed to stand in very hot water (150° F.) for two minutes. After about twenty-one months a fine crack appeared, which has expanded to its present dimensions. The brilliant polish has diminished, but the colour is as vivid as ever. A slight blister has appeared in the centre of the groove. Nevertheless, the brush is still being used and appears "as good as ever" and, although the crack indicates serious weakening, is still very strong. Moreover, probably because of the brilliant red of the resin, the crack is not as visible as the black and white photograph seems to indicate.

As for the black brush shown on the right, this has had a less strenuous test. It has been in continuous use for fourteen months for ordinary nail-scrubbing purposes, but has not been immersed in very hot water afterwards. Outwardly there appears to have been no change whatsoever. No cracks have appeared, nor has the brilliant lustre of the resin diminished.

These tests speak well for this "luxury" trade resin, especially, also, since both brushes have been dropped a goodly number of times, due to careless handling. Moreover, it should be noted that since 1937, when both were bought, improvements in quality have been made in the manufacture of cast resin.

## Resin Impregnation of Paper, Fabric and Wood.

The impregnation of relatively large sheets of paper and other absorbent materials with resin, by using alcoholic solutions of resins in the first stage, has introduced a new raw material for a type of fabrication which is not possible by the moulding of powders. Since paper coating has long been known, continuous rolls of paper, say 6 ft. wide, can readily be impregnated with resin. It can therefore be readily realised that by consolidating under heat and pressure, a large number of these single sheets, a



Two cast-resin nail-brushes which have undergone severe and prolonged tests.
(See p. 22.)

[*Facing p.* 22.

thick and large sheet or block of solid construction is formed. The value of such structures of great strength, high dielectric properties or, alternatively, æsthetic appearance, is obvious.

**Production.**—The impregnating or dipping plant consists of huge machines which are, in effect, conveyor rollers. At one end a large roll of paper, some 6 ft. wide, rotates, carrying the paper sheet forward and down into a shallow tank running the width of the paper and containing a solution of the synthetic resin in alcohol. From this tank the paper, now wet and saturated with the solution, enters a long enclosed chamber, often 100 ft. or so long, through which hot and conditioned air is passed to remove the solvent, leaving the pure resin impregnated in the paper. By the time the paper leaves this heated chamber it is perfectly dry and is rolled on rollers at the other end of the plant. The paper now has the appearance of a translucent shiny sheet with a hard surface.

**Consolidation of Impregnated Paper—Laminated Sheet.**—The impregnated sheets are then cut into sizes suitable to the presses available. For the production of wall veneers or for electrical "boards," for example, sizes up to 6 × 3 ft. or 8 × 4 ft. are common.

A number of such sheets then, according to the thickness of the compressed "board" required, are placed one on top of another, placed between two highly polished metal sheets and compressed between the heated flat platens of a hydraulic press. The press may contain as many as a dozen platens, so that that number of laminated boards can be produced at the same time. The platens are heated by steam, giving a temperature of about 170° C. and a pressure of ½ ton to 1 ton per sq. in. is exerted on the sheet. The resin is thus heat-hardened to its final infusible condition. Sheets 1 in. thick and over can be made. Insulators of many types can be produced by sawing, drilling or otherwise machining thin or thick sheet. For the production of insulator tubing the impregnated sheet as produced on the dipping and drying machines is wound on to rollers and then cured on heated mandrils.

There is little difference between the manufacture of insulator sheeting and of wall and door veneers or table tops. Since the latter are utilised because of their decorative purposes, in addition to their resistance to water or alcoholic beverages, the top sheet

is coloured and decorated by a printed design. Many beautiful effects are thus obtained. Since laminated material is so readily worked by saw, inlays of different colours can be incorporated in a door or a table-top.

**Properties of Laminated Paper Sheet.**—The laminated materials are, on the whole, stronger than those made from moulding powder:

| | |
|---|---|
| Specific gravity | 1·3–1·4 |
| Compressive strength | 9–18 tons per sq. in. |
| Tensile strength | 4–6 ,, ,, ,, ,, |
| Cross break strength | 6–14 ,, ,, ,, ,, |
| Impact strength | 0·3–3·0 ft. lb. |
| Breakdown voltage (60 cycles) | 400–1,000 |

## Laminated Fabrics.

The same process of impregnation and consolidation can be carried out, utilising strong cotton sheet or other fabrics instead of paper. The resulting blocks or thick sheets (thicknesses of 10 in. are quite common) are extremely strong and are utilised for the fabrication of gear wheels and heavy duty bearings. Cylindrical blocks are first cut out of the laminated sheet and teeth are then cut by machining.

**Properties.**—The laminated fabric material for gear fabrication normally turned out by British manufacturers shows better results than the limits given under British Standard Specification 668 (*loc. cit.*).

## Average Manufactured Laminated Fabric.

| | |
|---|---|
| Tensile strength | 7–7½ tons per sq. in. |
| Cross break strength | 9–11½ ,, ,, ,, ,, |
| Ultimate crushing strength | 15–16 ,, ,, ,, ,, |

## Impregnation of Wood Veneers.

The impregnation of wood veneers is yet another technique that has been developed in recent years for the production of heavy insulating components and also for structures for heavy engineering. The process applied is described in the chapter devoted to engineering applications.

## Resin Emulsions and High-strength Moulding Sheet.

One of the most recent methods of obtaining high strength moulding materials is that of impregnating fabrics with emulsions of phenol-formaldehyde synthetic resins in water. Little is known about the actual fabrication, since great secrecy is maintained, but it is a method of great promise and considerable success has already been achieved. The main developments appear to have taken place in U.S.A., Germany and Great Britain.

Broadly speaking, the operations are those similar to the felt-forming processes carried out in paper manufacture. Cotton flock is floated and treated with a resin emulsion so that impregnation is thorough, and orientation and felting is obtained in the trough. Excess resin emulsion and water is removed by suction below, leaving the closely felted material behind. The latter is dried and flattened into sheet which can be moulded or, alternatively, shredded into small pieces and used as a moulding powder. Moulded articles made from these are stronger than those produced from any other moulding material. Claims have been made that they possess three to five times the toughness or impact strength of objects made from ordinary high-strength moulding powders made by incorporating resin and fabric on masticating rollers.

In Great Britain the material has so far been used only for electrical parts, but in the U.S.A., where it is termed resin board, applications have been wider. Refrigerator handles capable of withstanding very high shocks have been made, and it has also been announced that one company is making sewing-machine housings of the material, while the Ford Co. has made trunk compartment covers for motor-cars. The production of motor-car doors and, in view of its heat-insulating properties, refrigerator doors, has also been suggested as likely objects of future manufacture.

### Properties.

| | |
|---|---|
| Specific gravity | |
| Tensile strength . | up to 5 tons per sq. in. |
| Impact strength . | up to 12 ft.-lb. per sq. in. |

**Soya-Phenol-Formaldehyde Resins.**

With the object of producing a cheaper moulding powder, workers in the U.S.A. (U.S. Regional Soybean Industrial Products Laboratory, Urbana, Illinois) have been experimenting with considerable success with plastics made from the soya bean, which contains a high percentage of protein. Work on the protein itself, which was obtained after solvent extraction of oil, proved unsuccessful. The modern production of the plastic appears to be the treatment of the soya protein flakes with formaldehyde and then mixture on masticating machines with phenol-formaldehyde resins. Mouldable powders are thus made which have proved so satisfactory for some purposes that the Ford motor works in Dearborn are using them extensively for mouldings such as coil cases, accelerator pedals and even tractor seats.

## UREA AND ALLIED PLASTICS

This second large section of the thermo-setting plastics was first discovered by Pollak, a Viennese chemist, in 1924 and produced commercially in England about the year 1925.

It had been realised that synthetic resins of a light-coloured type would find a market which the darker phenol-formaldehyde resins could not enter with satisfaction. The answer came by the discovery of the urea-formaldehyde type.

**Manufacture.**—Urea is a white organic compound in powder form manufactured by the chemical interaction of two simple common gases, carbon dioxide and ammonia. By interaction with formaldehyde a syrup is obtained containing the first-stage resin. From this the solid urea resin, fusible and water soluble, is formed.

Like the phenol-formaldehyde resin, this is employed to make:

(*a*) Moulding powders, by mixture with fillers.
(*b*) Solutions for the impregnation of paper, cloth and wood for consolidated laminations.

**Moulding Powders.**—These are prepared by mixing the powdered intermediate stage resin with wood flour or finely shredded paper, and since this mixture is of a pure white, delicate pastel shade pigments can be added to give beautifully coloured

mouldings impossible of attainment with phenol-formaldehyde powders. The technique of high-pressure moulding from the powder is very similar to that carried out with the phenol-formaldehyde resins and, like these, the half-stage resin hardens under heat and pressure in the steel die to give rigid, hard, and infusible mouldings. It was with these powders that the first plastic cups and saucers were made for the picnic and nursery trades. That they are more strongly entrenched in these markets than ever speaks well for their utility and beauty. While they are not unbreakable, such mouldings, because of their lightness and strength, are very durable. Moreover, they are odourless and tasteless. Since those early days the use of these moulding powders has spread greatly, especially in the lighter industries. Translucent lamp-shades, radio cabinets, bottle-closures, buttons, cigarette-boxes, and other "fancy" containers for perfumes and powders and a host of other general applications are now commonly manufactured.

**Properties.**—The following data is for an average paper-filled moulding :

| | |
|---|---|
| Specific gravity . . | |
| Tensile strength . . | 4–5 tons per sq. in. |
| Cross break strength . | 4–5 ,, ,, ,, ,, |
| Breakdown voltage (60 cycles) | 700 |
| Water absorption . . . | about 1 per cent. (twenty-four hours' immersion). |

It will be seen from the above that although the water absorption is high, yet the moulded plastic possesses good electrical properties. It is also "non-tracking," and is, in consequence, in demand for special electrical components.

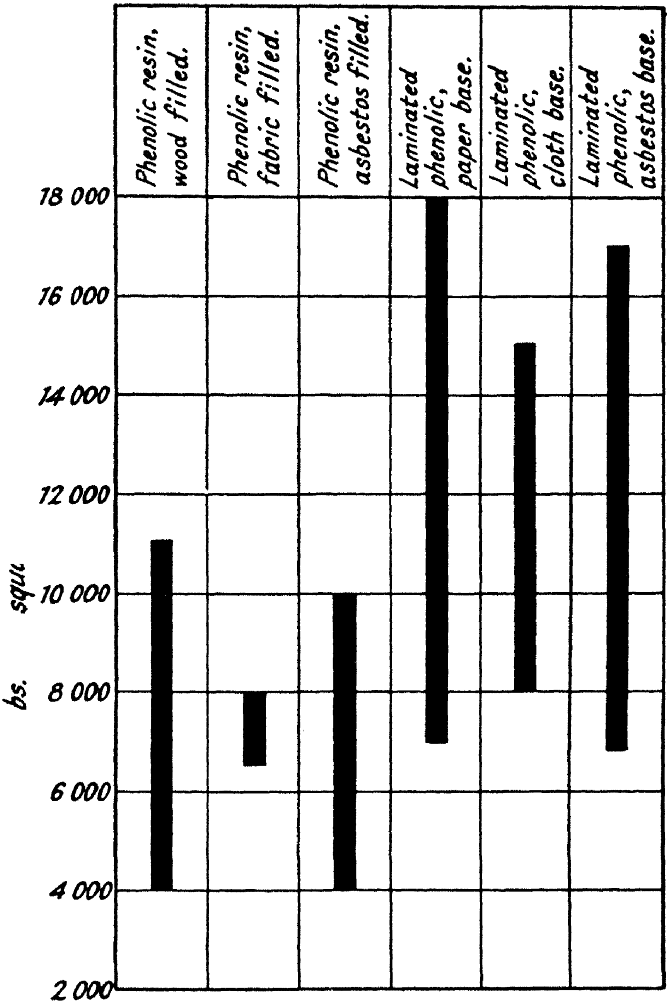
## Impregnation of Paper, Fabric, and Wood.

Impregnation of paper and the consolidation of such sheets is carried out in a manner similar to that described when using phenol-formaldehyde resin solutions. The principal uses of such sheet are for the production of table-tops and similar decorative and utility purposes. Alternatively, the urea resin solutions may be employed as glues for making plywood and similar structures, not only for furniture manufacture, but also for certain heavy industries, such as aircraft construction. The glues make ex-

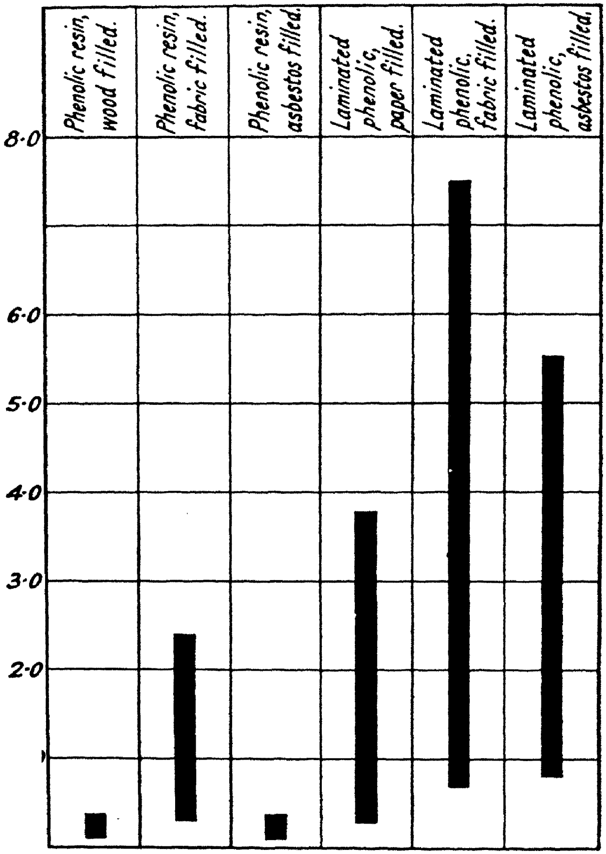
tremely strong jointings, which are unaffected by bacterial or fungus attack.

**Melamine-Formaldehyde Moulding Powders.**

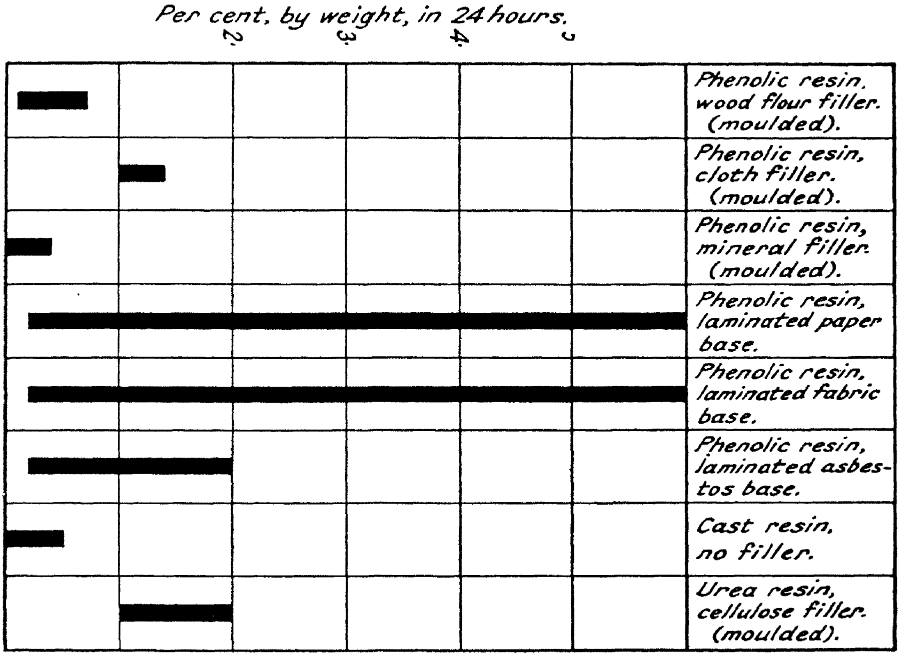
The melamine plastics are included in this section since, like urea, melamine contains what is chemically called an "amino" (ammonia) group in the molecule. Both types are thus somewhat allied in character and appearance, and, indeed, melamine resins are employed for much the same purposes as urea resins. The advantages claimed for parts moulded of melamine resins are stability in the presence of heat and hot water and fruit juices. They produce beautifully coloured mouldings, and in some countries are usurping the position held by urea mouldings for the manufacture of cups, saucers, and other table ware. Little use of them is made in Great Britain. They are of Swiss origin.



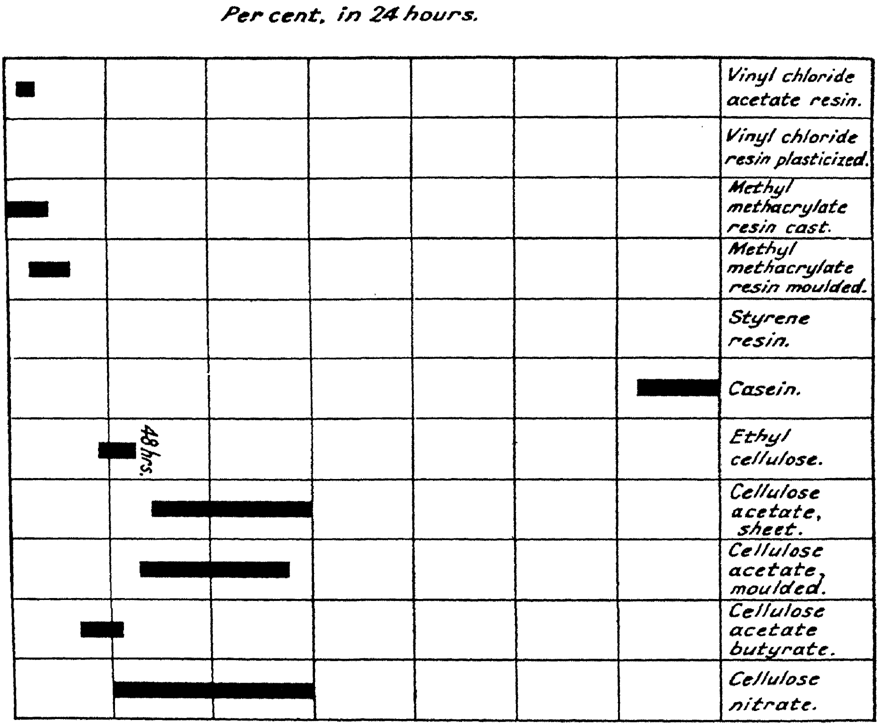

Tensile strengths of the best-known types of phenolic resins. The heavy black lines show the wide ranges available to the industrialist.




Impact strengths of the best-known types of phenolic resins, indicating their relative ability to withstand shock.




Relative water-absorption of thermo-hardening plastics.




Relative water-absorption of thermo-plastics. (Note : The figure for styrene resin is nil.)

## CHAPTER III

# SPECIFICATIONS

ONE of the most powerful instruments of control in modern industry, in mass production and unit construction alike, is the official specification. It is both an arrow pointing to an ideal and a means of raising the quality of general production.

It will therefore be a disappointment to the engineer that specifications for plastics are largely lacking. This lack, on the other hand, is understandable in view of the youth of the plastic industry, because methods of test that apply to metals cannot always be applied to plastics, and consequently new ones have to be devised and, moreover, because change is very rapid. The industry, internationally and nationally speaking, is far from being organised sufficiently to permit of official specifications.

On the whole, the situation is as follows. All the great consumer companies throughout the world, especially the electrical companies, have their own specifications and have devised their own tests.

Since the most important plastics began their useful life in the electrical industry, the first specifications were necessarily built up on electrical tests only. There was little difficulty in making these, since the phenol-formaldehyde mouldings approach sufficiently near the older materials in physical properties.

On the whole, Great Britain appears to have advanced more than any other country in the matter of official specifications.

In 1929 there first appeared British Standard Specification 316, which deals with synthetic resin varnish paper boards and tubes, Grade II (low resin content), while B.S.S. 547 (1934) deals with Grade I (high resin content). The tests on these materials are almost identical—electric tests, mechanical tests, water absorption and the effect of hot oil. Grade I also undergoes

a test for surface insulation after a "tropical" conditioning test. Both specifications are widely employed by manufacturers in the electrical industry.

In 1936 B.S.S. 668 was devised to standardise Laminated Synthetic Resin Bonded Sheet (Fabric Base).

In addition to the usual mechanical, water absorption, and hot oil tests the specification includes "Tolerance on Dimensions" and machining tests. There are no electrical tests, nor has a toughness test been published yet.

Among the specifications are:

| | |
|---|---|
| Tensile strength . | not less than 8,500 lb. per sq. in. |
| Cross break strength . | ,, ,, ,, 16,000 ,, ,, ,, ,, |
| Water absorption . | not more than 0·6 per cent. (24 hrs.). |

### Thermo-Setting Resin Mouldings.

As the plastics moulding industry widened its scope, the need for specifications for actual mouldings from phenol-formaldehyde resin powders assumed great importance. In 1938 B.S.S. 771, referring solely to this type, appeared. It deals not only with the raw materials, but also with the finished mouldings. For the latter, simple tests, such as freedom from obvious defects, specific gravity, finish and degree of cure (controlled by acetone extraction) are specified.

The moulding powders are classified under five headings:

| | |
|---|---|
| G | General type. |
| GX | Improved type. |
| MS . | Medium shock resistant type. |
| HS . | High shock resistant type. |
| HR . | Heat resistant type. |

The electrical and mechanical tests carried out on these are very similar to those carried out in B.S.S. 488. In addition the heat-resistant type is tested for resistance to crushing after heating to high temperatures.

It must be pointed out that the methods of tests themselves must be carefully examined before the figures given are compared with those specified in other countries.

## SPECIFICATIONS

As examples we can quote HS and HR materials:

| | *HS* | *HR* |
|---|---|---|
| Ultimate tensile strength | 6,000 lb. per sq. in. | 3,500 lb. per sq. in. |
| Impact strength (Izod) | 0·90 ft.-lb. | 0·07 ft.-lb. |
| Water absorption | 350 mg. | 100 mg. |
| Electric strength at 90° C. | 20 volts per mil. | 20 volts per mil. |
| Surface resistivity after water immersion | 100 megohms. | 100 megohms. |
| Resistance to crushing after heating to 400° C. in bath of fusible metal | | 500 lb. |

*Plastics* (London), July, 1939, published some additional notes regarding tentative and unofficial specifications of other plastic materials.

### AMINO-PLASTICS

There exists at present no British Standard for amino-plastics, but two principal manufacturers are preparing the ground for a specification. They will probably follow the general lines of B.S.S. 771, but with modifications, such as thinner test pieces, the replacement of the acetone extraction test after curing by immersion in water, followed by a scratching test. It does not seem probable that any specification for amino-plastics will be introduced before the end of the present war.

Some of the proposals are as follows:

*Tensile Strength.*—Test piece as in B.S.S. 771, but reduced by ⅛ in. all over. Standard as for GX Phenolic. 7,000 lb. per sq. in.

*Impact Strength.*—No agreement has been reached, but results are about the same as on a good wood-filled phenolic under the same tests.

*Water Absorption.*—As B.S.S. 771, but higher figure, about 350 mg., will have to be allowed.

*Electric Strength and Surface Resistivity.*—As B.S.S. 771. Electric strength similar to phenolics, and surface resistivity is generally better.

*Flow of Moulding Material.*—The cup flow method is not suitable for amino-plastics. Perhaps some type of flat disc method may be adopted.

*Resistance to Electrical Tracking.*—In view of the non-tracking

properties of amino-plastics, some test for this will be included. A simple type of test is being considered, in which two metal studs inserted about $1\frac{1}{2}$ in. apart in a flat moulding are connected to a 230 volt A.C. supply choked to about 10 amps. and the circuit completed by pouring 10 per cent. salt solution on the moulding. Amino-plastics should not track, even after repeated application.

## THERMO-PLASTICS

**Cellulose Acetate.**—This material and celluloid are so different chemically from all other thermo-plastics that it is worth while repeating in full the information regarding standards given by one of the producers in Great Britain.

There are very few British Standard Specifications for plastics made from cellulose esters. The reasons for this are threefold:

(*a*) Manufacturers are in some cases unwilling to adopt specifications for materials which are still in process of development and improvement.

(*b*) Cellulose ester plastics are not chemical individuals, and therefore tolerances must be allowed not only in the chemical composition of the ingredients, but also in the proportions and even the identity of the plasticisers. This opens such a wide door that a specification becomes of little use.

(*c*) Cellulose ester plastics are used for a variety of purposes. A specification which would be acceptable for a plastic required for one particular purpose would usually be at fault for the same plastic if required for another purpose.

It follows from this that the service which standardisation authorities can render to the plastics industry lies more in defining the properties which are required for particular purposes than in standardising individual plastics, and it may be pointed out that the adoption of this principle gives much better opportunities to new plastics, which can then compete on equal terms with old-established plastics.

The British Standard Specifications dealing with Cellulose Ester Plastics are:

2D.50—Cellulose Acetate.
F.56—Transparent Sheets for Observation Panels.

*B.S.S. 2D.50. Cellulose Acetate.*—This specification is for cellulose acetate base, and includes tests for stability to moisture and heat, water content, filming capacity, acidity, ash and viscosity. Methods of applying these tests are described in appendices.

This specification defines a good merchantable cellulose acetate, suitable, for example, for high-quality dope manufacture, but it cannot be regarded as guaranteeing a quality suitable for high-grade transparent sheet.

*B.S.S. F.56. Transparent Sheets for Observation Panels.* The title of this specification does not indicate that it applies to cellulose acetate, but the first clause runs: "1. Type of Material. The sheets shall be made from a stable variety of cellulose acetate and suitable softening or plasticising agents." The remaining clauses deal with freedom from defects, dimensions, selection of samples, transparency, freedom from brittleness, rigidity, resistance to extremes of temperature, resistance to moisture, combustibility and resistance to accelerated ageing. Not one of the tests described is specific to cellulose acetate, so that, apart from the first clause, this specification defines properties required rather than an individual plastic. It is now being revised.

There is an Air Ministry Specification D.T.D. 315 for pigmented cellulose acetate sheets which follows the general lines of B.S.S. 2D.50.

There are also various confidential Government specifications for celluloid and cellulose acetate products, the contents of which cannot be published. These have been and are still negotiated between the manufacturer and the Government departments using plastic materials.

**Methyl Methacrylate.**—The following relates to Diakon and Perspex, both thermo-plastics made by I.C.I. Ltd. and based on methyl methacrylate. The former is in granule form for moulding and the latter is in cast rod or sheet form. No British standards exist, but the manufacturers carry out tests to their own specifications, and in the case of Perspex sheet there is an Air Ministry specification in use, D.T.D. 339a.

(*a*) *Cast Sheet.*—Apart from specification of surface appearance and thickness, this sets limits for the loss of light by absorption and reflection, the tensile strength, the rate of burning, the impact strength (as measured by a ball falling on to a sheet supported in a specified manner), change in dimensions and

transparency after soaking in water and after heating, and after exposure to arc light.

The specified limits are:

| | |
|---|---|
| Tensile strength . | greater than 2·75 tons per sq. in., less than 4·25 tons per sq. in. |
| Light transmission | not less than 90 per cent. after all treatments. |
| Change of dimensions | not greater than 0·5 per cent. after all treatments. |

The burning rate and the specified height of fall for the ball naturally vary with the thickness of the sheet but as examples the figures for a $\frac{5}{32}$-in. thick sheet are:

> Time to burn down 6 in. of 1 in. wide not less than 13 minutes. Material must not fail when 130 gram ball is dropped 2 ft. 11 in.
>
> Material supported on steel supports at three points distant $3\frac{1}{2}$ in. from each other.

The tensile and compressive strength of Perspex vary with temperature as follows:

| | *Ultimate Tensile Strength.* | *Proportional Limit in Compression Strength.* |
|---|---|---|
| −60° C. . | 6·2 tons per sq. in. | — |
| −40° C. . | 6·1 ,, ,, ,, ,, | 11·0 tons per sq. in. |
| −20° C. . | 5·7 ,, ,, ,, ,, | 7·2 ,, ,, ,, ,, |
| 0° C. . | 4·9 ,, ,, ,, ,, | 5·5 ,, ,, ,, ,, |
| 20° C. . | 3·7 ,, ,, ,, ,, | 4·4 ,, ,, ,, ,, |
| 40° C. . | 2·5 ,, ,, ,, ,, | |
| 60° C. . | | |

The proportional limit instead of the ultimate strength is given in compression, since at the higher temperatures the material does not fracture under increasing loads, but merely flows.

(*b*) *Moulding Powders.*—Certain of the methods of test and test-pieces, specified in B.S.S. 771 for phenolic moulding powders, are applicable, but of course the moulding conditions have to be adjusted and the moulds must be cooled before ejecting the specimens. The heat resistance is conveniently measured by means of the Martens test. Typical figures for Diakon are:

| | | *Diakon F.* |
|---|---|---|
| Specific gravity . . . . | | 1·19 |
| Bulk density . . . . | | 0·7 |
| Bulk factor . . . . | | 1·7 |
| Water absorption (7 days) . | | 0·24–0·30 |
| Shrinkage on moulding . . | | 0·002–0·006 |
| Martens point (° C.) . . . | | 55–60 |
| Tensile strength (lb. per sq. in.) | | 8,200–10,000 |
| Impact strength (as B.S.S. 771) | | 0·30–0·35 |
| Ultimate fibre stress in bend (lb.) | | 11,000–14,000 |
| Brinell hardness . . . | | 19–21 |
| Surface resistivity (megohms) . | | $> 10^{10}$ |
| Volume resistivity (megohm cm.) | | $> 10^{9}$ |
| Permittivity at $5 \times 10^7$ cycle . | | 2·6 |
| | | 2·9 |
| | | 3·6 |
| | At 20° C. and | 4·0 |
| Power factor at $5 \times 10^7$ ,, | 75 per cent. | 0·022 |
| ,, ,, ,, ,, $10^6$ ,, | humidity . | 0·019 |
| Power factor at 800 cycle | | 0·033 |
| ,, ,, ,, 50 ,, | | 0·038 |
| Dielectric strength at 20° C. | | 280–300 |
| ,, ,, ,, 70° F. | | 280–300 |

The material retains its impact strength practically unaltered down to a temperature of — 60° C.

With coloured Diakon, as with urea-formaldehyde, it is probable that a colour permanence test will be considered in drawing up any British Standards, since perfect colour stability can be obtained by choice of stable colouring materials.

**Polystyrene.**—Here there are no official standards at all in this country. The following figures represent the unofficial standard to which one manufacturing concern works with its own product; this material is Distrene, which is manufactured by the Distillers Co. Ltd.:

*Moulding Conditions.*

| | |
|---|---|
| Compression moulding temperature | 140–180° C. |
| ,, ,, pressure | 1,500–500 lb. per sq. in. |
| Compression ratio . . . | 1·93–2·05. |
| Mould shrinkage . . . | about $\frac{5}{1000}$ in. to the inch |
| Injection moulding temperature . | 170–200° C. |
| ,, ,, pressure . | $1\frac{1}{2}$–10 tons per sq. in. |

*Physical and Mechanical Properties.*

| | |
|---|---|
| Specific gravity | 1·05 |
| Refractive index | 1·62 |
| Specific heat, cal. per ° C. per gram | 0·324 |
| Thermal expansion, $10^{-5}$ per ° C. | 7·2 (− 10° to 45°) |
| Softening point, Martens | 87° C. |
| Distortion temperature (A.S.T.M. D48–37) | 80–90° C. |
| Thermal conductivity | $10^{-4}$ cal. per sec. per sq. cm. per 1° C. per cm., 1·9 |
| Tensile strength | 2·7–3·0 tons per sq. in. |
| Elongation | 0·5–1 per cent. |
| Modulus of elasticity (lb. per sq. in. × $10^5$) | 5·5 |
| Compression strength (tons per sq. in.) | 7 tons |
| Flexural strength (tons per sq. in.) | 3–3½ tons |
| Impact strength : | |
| Izod, notched bar (ft. lb. 25° C.) | 0·25–0·3 |
| ,, ,, ,, (ft. lb. − 70° C.) | 0·25 to 0·3 |
| Brinell no. (2·5 mm. ball, 25 kg. load) | 20–30 |
| Rockwell hardness no. (½-in. ball, 60-kg. load) | 90–97 |
| Rockwell superficial hardness (¼-in. ball, 15-kg. load) | 15 × 90 |
| Light transmission through 0·1-in. plate | 90 per cent. |
| Water absorption in 48 hrs. | nil |
| Effect of ultra-violet radiation | yellows slightly |
| Effect of dilute acids | none |
| Effect of alkalis | none |
| Effect of $H_2O_2$ 100 vol. | none |

*Electrical Properties.*

| *Frequencies.* | *S.I.C.* | *Loss Factor.* |
|---|---|---|
| 50 | 2·2 | 0·0002 |
| 1,000 | 2·2 | 0·0005 |
| 200,000 | 2·1 | 0·00044 |
| 650,000 | 2·1 | 0·0002 |
| 1,000,000 | 2·3 | 0·0002 |
| 40,000,000 | 2·3 | 0·0001 |

| | |
|---|---|
| Breakdown voltage, 50 cycles, volts per mil. | 500–700 |
| Volume resistivity, ohm-cm. | $> 10^{17}$ |
| Surface resistivity, ohms | |

**Vinyl Plastics.**—Here again there are no specifications and the only data available to us are certain physical and chemical constants for the Gelvas, Alvars, and Formvars imported into Great Britain by Shawinigan Ltd. These are derived from vinyl acetate.

**Gelvas.**

| | |
|---|---|
| Dielectric strength . . . | 1,000 volts per mil. |
| Dielectric constant (30° C.) . | 2·7 |
| Coefficient of linear expansion . | 0·000086 |
| Water absorption (A.S.T.M.) . | 2·0 |

There are seven gelvas manufactured, varying in softening point from 65–196° C. The harder Gelvas have a tensile strength of 5,000 lb. per sq. in.

**Alvars.**—These plastics resemble closely the Gelvas in electrical properties and water absorption. Five are manufactured, varying in softening point from 120° C. to 180° C. The Alvar with 170° C. softening has a tensile strength of 7,500 lb. per sq. in

**Formvars.**

| | |
|---|---|
| Dielectric strength . . | 1,000 volts per mil. |
| ,, constant (30° C.) . | 3·7 |
| Tensile strength . . . | 14,600 lb. per sq. in. |
| Water absorption . . . . | |
| Softening points (2 varieties) . | 190° C. +, and 250° C. + |

The Formvars find application for moulding powders, sheets, rods and tubes, and for the manufacture of safety glass.

## SUMMARY

The foregoing are almost the only specifications in existence in Great Britain. Those that are not the official issues of The British Standards Institute are the normal specifications utilised by manufacturers of the raw moulding powders and other plastics themselves, just as any chemical manufacturer must employ to control his output or to advise his customers. As indicated already, all big electric or other plastic consumers possess their own specifications—many of course in Great Britain, as in the U.S.A., France, Germany, etc., mould for their own consumption. This method is also applicable to Government Departments.

Such specifications generally follow the standard specifications, but, for obvious reasons, differ on occasion. For example, the British Air Ministry ask the moulder who is quoting for a tender for a thick moulded plate which is cut up into specimens for testing and these latter may be cut out from the very centre of the plate. Some criticism has been levelled against this method as being too stringent, but this may be countered by the obvious retort that stringency must be expected in dealing with aeroplane parts.

There is, in fact, a criticism regarding the specifications in general, namely, that they are tests of moulding rather than of tests on the moulding powder. It has been said that it is unfair to expect powder manufacturers to mould as well as expert moulding manufacturers and, moreover, that more exact conditions of moulding should be defined. There are many tricks in the trade which influence the final properties of the moulded object. So much, too, depends on the type of press available.

The experience of the General Post Office, however, is interesting. When a powder is submitted in order that it may be placed on the Approved List, the G.P.O. state that specimens submitted may be moulded by the manufacturer or any moulder he chooses, although in general, the powder manufacturer will wish to make them himself for purposes of control and convenience. When the powder is placed on the Approved List the moulder who wishes to supply finished goods made from it must convince the G.P.O. that he can produce satisfactory mouldings. There is thus a double check. An official of the G.P.O. states that the moulding produced by the powder manufacturer is, on occasion, better than that produced by the moulding concern.

Whilst on the subject of the G.P.O., it is worth while noting some of the tests they carry out. Generally they follow B.S.S. 771, but for special objects special tests are made. Thus for the guard and plunger of the modern telephone an additional impact strength test is made on the whole piece, and is reported as such and not calculated on unit area. The blow on the guard, for example, is given at right angles to the horn at one spot. For cellulose acetate results of 2–4 ft. lb. are obtained. It is now generally known, perhaps, that cellulose acetate is used for the black G.P.O. guards and "acrylic" resins for the coloured ones.

Colour fading tests are carried out, now that coloured telephones are widely used. The mercury lamp, which was originally used for the test, has proved useless because of its narrow band of light and has given place to the carbon arc.

A new telephone apparatus, the Swedish type, is now being issued, but the method of testing has not yet been decided upon. It is not known yet where the main strains will occur.

## CHAPTER IV

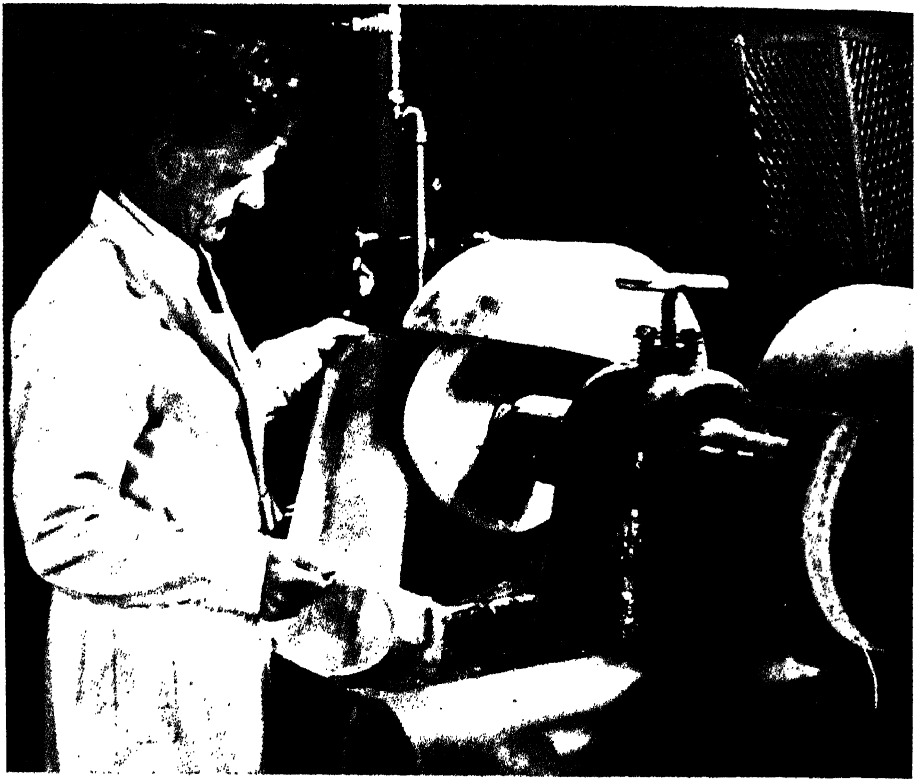
# MOULDING AND FABRICATION TECHNIQUE

HERE, again, it is not proposed to describe in great technical detail the methods by which plastics are fabricated into their finished forms. Such notes as are given here are intended merely for the better understanding of the plastics industry as a whole. They serve, too, to amplify the data already given on the physical properties of plastics.

All the fabricating operations carried out on plastics can, of course, be considered as moulding, but in practice the nomenclature of the processes adopted is as follows:

1. Blowing or shaping of thermo-plastic sheet.
2. Extrusion through nozzles or dies. This process applies to both thermo-plastic and thermo-setting plastics.
3. Compression moulding. This is the most general method adopted in fabricating from thermo-setting moulding powders. It is rarely adopted for thermo-plastic powders.
4. Injection moulding. Almost solely used for moulding thermo-plastics. Injection of thermo-setting resins has been examined, but success is, so far, limited.

The above four methods are carried out by the plastics moulding industry—a purely engineering industry. This makes use of sheet, powders, etc., which it buys from the raw materials or chemical manufacturers. While it is true that some raw material manufacturers also mould finished objects and some moulding concerns make their own synthetic resins for "political" reasons, this practice is very rare. It is not necessary, therefore, to include "Casting" in this section, since castings are made by the synthetic resin manufacturers and are sold to those concerns fabricating objects therefrom by additional but purely machining operations. Under this section, therefore, will also be given some



The polishing of cast methyl methacrylate resin (Lucite) in the form of tubes.

*(Courtesy E. I. Du Pont de Nemours.)*

*Facing p.* 45.]

notes regarding some of the machining operations that can be carried out on these and other plastics, such as laminated material.

**Blowing and Shaping Thermo-Plastics from Sheet, Rod, etc.**—Most of the processes for the working of these plastics are derived from the early methods adopted by the celluloid industry. Excellent examples of combs and other shaped pieces made from celluloid about the year 1855 can be seen in the Science Museum in London, and many of the methods of manipulation evolved during those early days are still practised. Success in this type of work depends on the individual skill of the worker, since it is nearly all hand work. Bending of thin sheet, for example, is done by placing the piece on a hot plate for a few seconds, bending to the required shape, with or without a template, and then plunging into cold water. Rods may be bent by placing them in hot sand.

**Blowing.**—Many hollow fancy goods and toys are produced in celluloid or acetate by this process, in which two metal dies in a press are employed. In principle, two heated sheets of the plastic are held between steam-heated upper and lower dies and by the injection of air between the sheets are moulded into the dies. The sides of the sheets coalesce under the heat, forming a hollow shape, and the dies are cooled with cold water. On opening the press the moulding is removed.

**Shaping of Large Plastic Sheet.**—While, fundamentally, there is no difference between this process and simple bending of thin small-sized sheets, it is described, because of recent years the application in industry of very large sheets of thickness ¼ in. and even over has grown very rapidly. Enormous quantities of "organic glass," that is, cellulose acetate, and "acrylic" resin sheets are required for the windows and gun-turrets of aircraft, while the use of opaque acetate sheet is steadily increasing for ventilator ducts, ammunition chutes, etc., in the same industry.

Increase of size and increasing complexity in design has, however, necessitated the introduction of special plant. The heating of sheets of 1 sq. yd. surface obviously calls for large ovens thermostatically controlled, and the shaping of them has brought into use special moulds and jigs to hold the sheet in place while it is being cooled. The production of moulds and jigs, which are usually of hard wood, are often excellent examples of the engineer's skill, especially when it is realised that double curvatures in the

plastic are often required, that high-dimensional accuracy is necessary and that no uneven strain on the sheet during forming must be exerted.

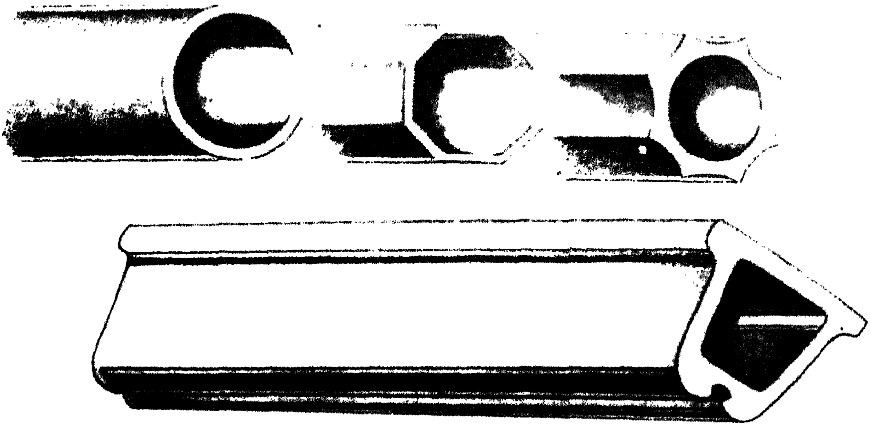
The sheet of plastic is heated in an electric oven maintained at about 120° C. Usually the sheet is hung up by means of clips, one clip being used to hang the sheet on a strong wire: another clip allows for removal of the sheet when it is soft and workable. When this state is reached it is quickly removed from the oven by the operator, who draws it firmly over the mould, using the two clips to secure a grip. The jig is then closed and the plastic sheet kept stretched over the mould until it is cold and rigid.

Trimming to design or removing waste may be carried on while the sheet is soft by means of shears, or, alternatively, when cold by sawing. These plastics have no grain : they lend themselves admirably to most types of machining, such as bevelling, drilling, turning, etc. Jointing pieces of acetate or " acrylic " resin sheets is readily carried out with satisfaction by the use of simple organic solvents, scarf and strap joints being widely employed. The surfaces may be buffed and highly polished to a glass mirror finish, or, alternatively, matt-surfaced by spraying with organic solvent.

**Extrusion.**—This process, which originated with the production of celluloid and casein rods or tubes and also of rubber tubes, has, in recent years, been adopted for many of the new thermoplastics and even for thermo-setting resins.

The method is essentially the forcing of plastic by means of a plunger through a heated nozzle of simple circular or square cross-section if a rod is required. If a tube is to be made then a concentric mandril is introduced, the plastic being extruded in the annular space between the two. This method of producing cellulose acetate tubing, for example, is preferred by many users instead of the older method of shaping an oblong piece of thin sheet and then " welding " the seam. Much thicker tubes can be produced by extrusion, and the complete absence of a joint is welcomed.

Extrusion is now commonly carried out on the polyvinyl and polythene type of plastics for making electric cable covers and for producing continuous coloured strips or ribbons for shoe and belt manufacture. It is understood, also, that water and chemical piping of similar materials have been extruded in Germany.



Extruded phenolic resin tubes, etc.
The bottom example is a curtain roller suspension.

The versatility of the injection moulding process: 92 letters of Tenite cellulose acetate moulded in one mould.

*Facing p.* 47.]

Within the last few years some extrusion of thermo-setting resins of the phenolic and urea types has been successfully achieved, notably in Great Britain.

The method adopted, although on broad principle the same as that utilised for the thermo-plastics, differs in the internal mechanism of the extrusion machine in that here the moulding powder must be compressed and heated to flow point in one section, heated until cured in another, and finally cooled on its way to the exit spacing.

The first successful extrusion of thermo-setting resins on a manufacturing basis in Great Britain was that carried out about 1936 for the production of duplicator cylinders by Gestetner Ltd. of London, using a phenol-formaldehyde moulding powder. It is still being carried out with great success. The machine employed is a Werner-Pfliederer extruder. This is a continuous automatic extrusion type and consists of a resin feeding chamber, a ram actuated by a hydraulic three-throw pump and an electrically heated die which feeds on to a mandril about 4¼ in. diameter. The extruded tube is thus this width in internal diameter and about ¼ in. in wall thickness. The following description of the manufacture is given in *Plastics*, June, 1937, p. 35:

> In order that there should be no clogging of the feeding chambers by premature curing, there must be no heating before the resin powder enters the die proper. The ram, therefore, first presses the powder into a chamber which is maintained at a low and constant temperature by cold-water circulation in a surrounding jacket. The resin powder is thus maintained in a compressed form some inches before it enters the die. The die or curing chamber is an annular space some 9 in. long and is progressively heated along its length by three electric elements "stepped up" to obtain successive temperatures of 130°, 160° and 180° C. As the time of cure in this 9-in. length is about 1½ minutes, the ram works to an output of some 6 in. of tube per minute. About 14 miles of tubing have been turned out during the last year. The finished tube issues on the mandril and is sawn off in convenient lengths after close optical examination for faults such as scorching.

About 1938 British Industrial Plastics Ltd. produced extruded tubes of varying cross-section of urea resins with complete success, the beautiful colours thereby made allowed the product to enter the "home" trade in the shape of towel-rollers.

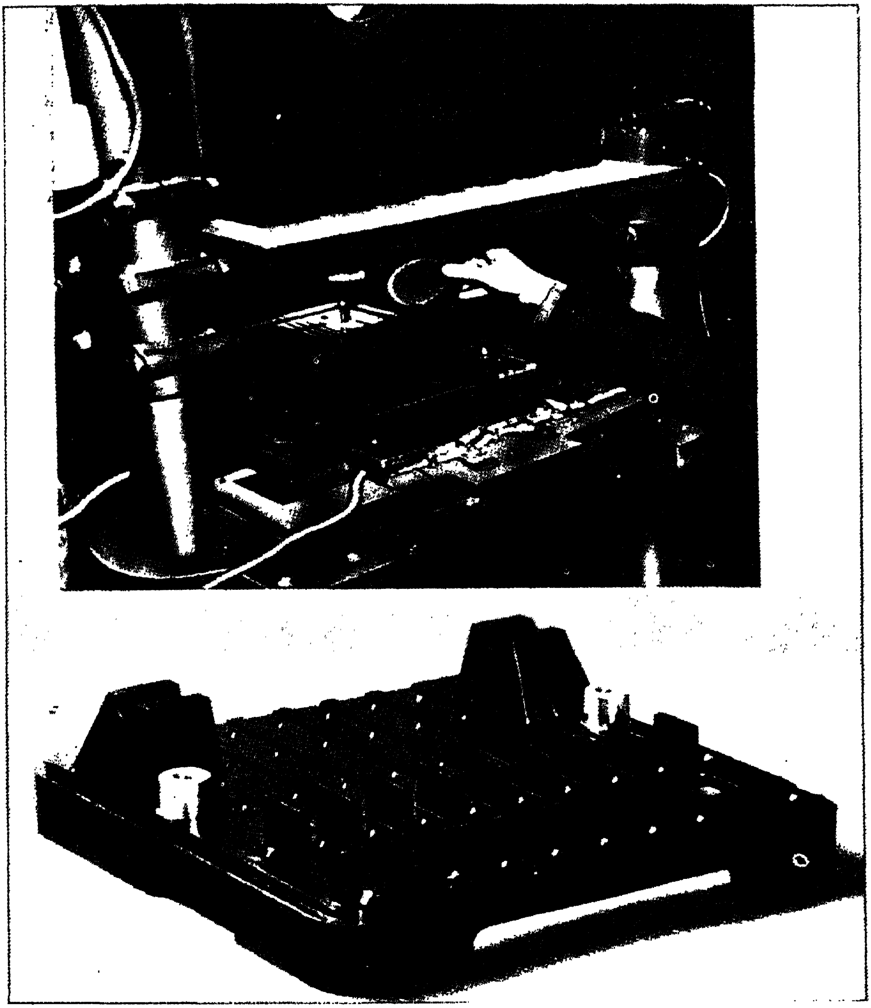
About the same time Cellomold Ltd. produced a wide range of extruded phenol-formaldehyde tubings of a cross-section especially designed for curtain roller suspensions. One of these shown facing p. 47 is probably one of the thickest and strongest plastic extrusions so far made.

**Compression Moulding.**—This type of moulding is carried out most commonly on the phenol and urea moulding powders, that is, the thermo-hardening synthetic resin plastics. It consists in placing a quantity of the powder or a compressed tablet of the powder in the lower half of a heated mould, held on the platens of a hydraulic or mechanical press. The top or plunger half of the mould is then lowered, slowly compressing the plastic, which, under the hot conditions of the press, flows into every cavity of the space between the top and lower halves.

In practice the quantity of powder required to make the finished moulding is carefully weighed with a slight excess and emptied into the lower cavity and the top plunger slowly lowered, using at first a comparatively low pressure of the order of 300 lb. per sq. in. for some few seconds. During this period the mould is not entirely closed, but soon the pressure is increased to slightly over 1 ton per sq. in. and the mould is finally closed. The moulds are heated by steam or electricity to a temperature of about 350° F. and the moulding is held therein until final hardening takes place. This period varies greatly with the thickness of the moulding, temperature, etc., but is generally of the order of ½ minute to 1½ minutes for thin or relatively small objects. Obviously, before carrying out continuous production a number of tests are carried out to ascertain the best temperature and curing times under which a particular moulding must be produced.

The plunger is raised as soon as the period of "curing" has elapsed and the finished moulding is either removed by hand or ejected with special pins. In most cases the moulding needs no finishing, with the possible exception of the removal of excess powder or "flash" that has been squeezed out between the upper and lower halves of the mould and which remains adhered to the moulding.

The moulds are made of special steels and when moulding urea powders must be chromium plated to prevent discoloration. It is interesting to note here that with the increased importance of rapid output the mould is usually machined to take more than one

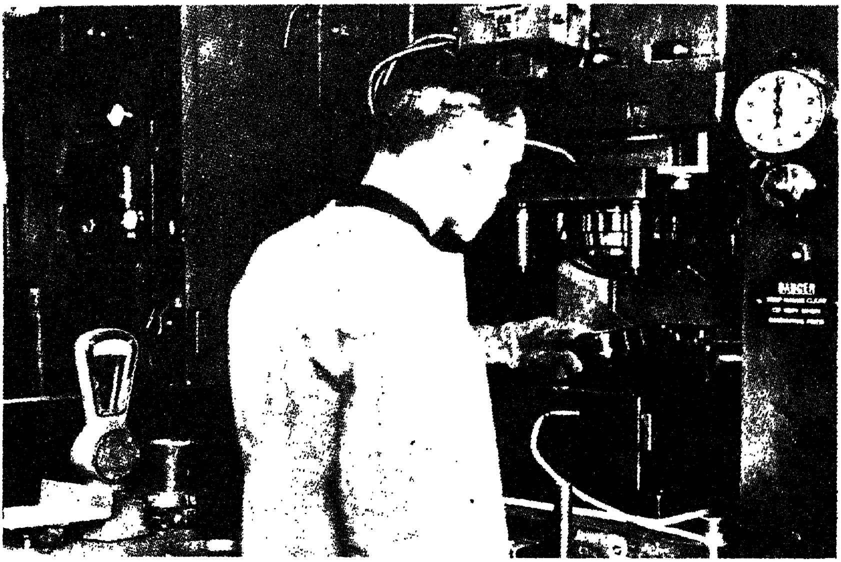


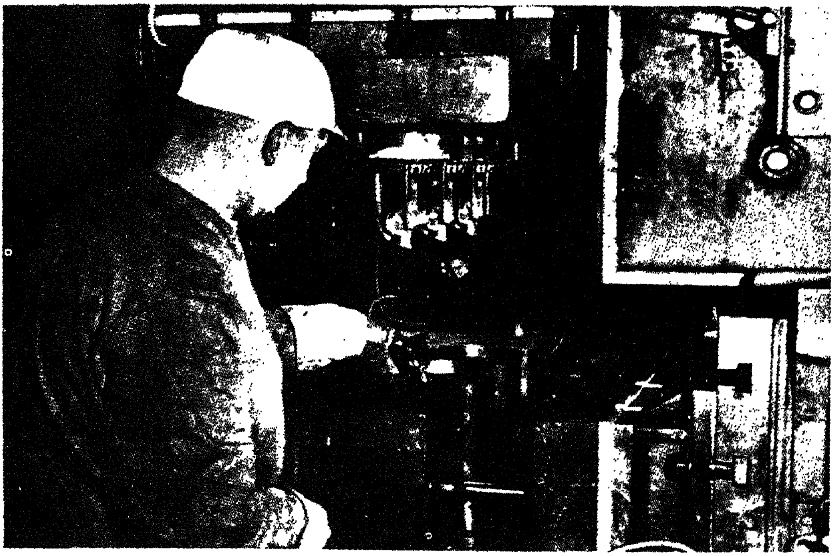
Compression moulding.

ABOVE: Loading the lower half of a mould with a cupful of moulding powder.

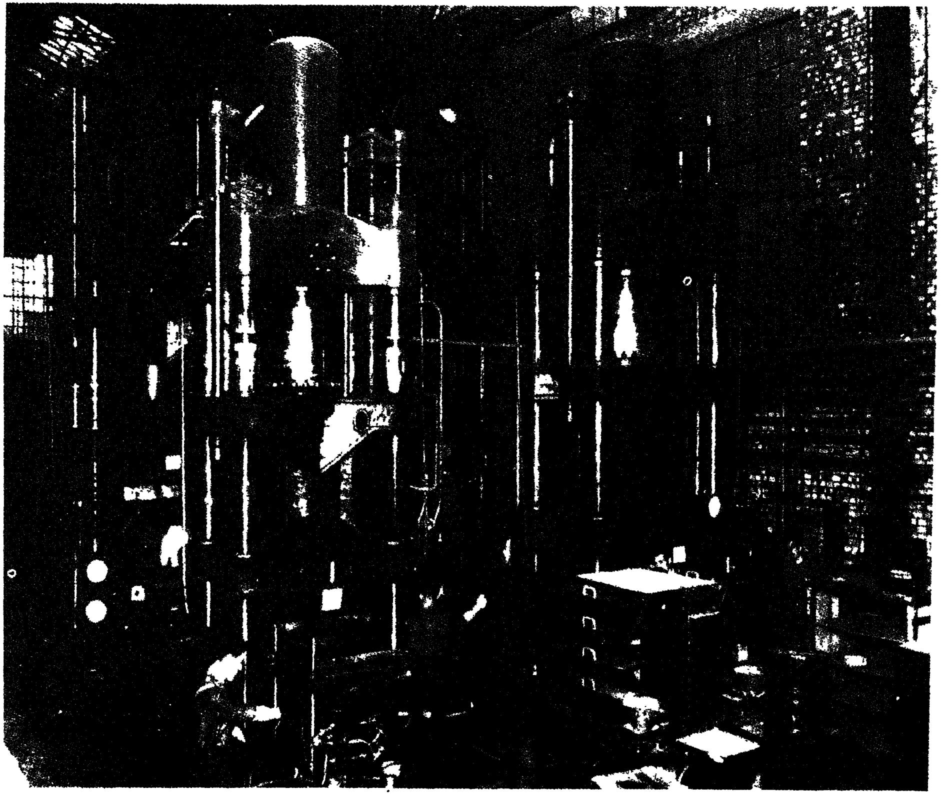
BELOW: The electrical component (fitted with two metal inserts) made from it.

[*Facing p.* 48.

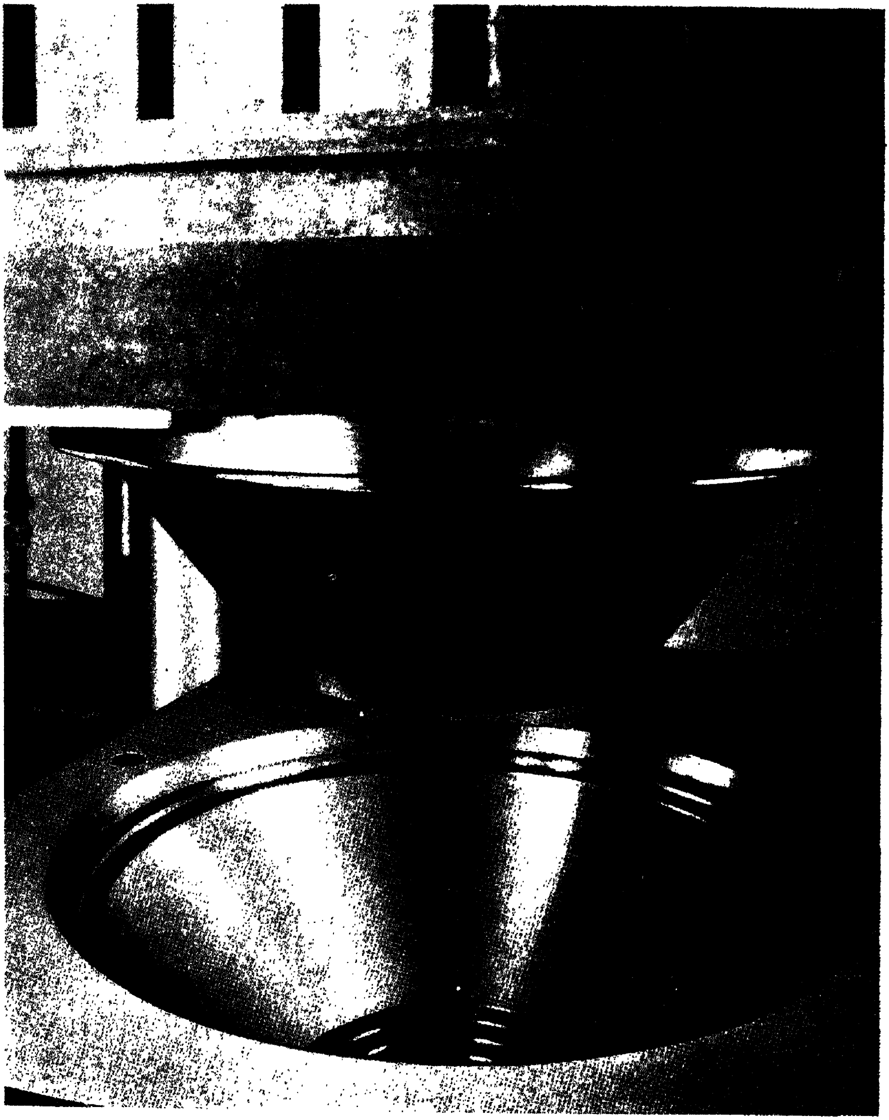




Two different types of presses used by Hoover Ltd. for moulding Hoover components from phenol-formaldehyde resin moulding powder.



Moulding radio cabinets at the works of E. K. Cole, Ltd., on 2,000-ton presses.



G.E.C. mould weighing 5 tons, for producing 26½-inch light reflector from urea moulding powder.

*Facing p.* 49.]

"shot" of powder. For medium-sized mouldings it is quite common to produce 4 to 6 in one mould, while in the small sizes, such as black piano keys, 30-impression moulds have been employed.

In the ordinary vertical plunger type of mould undercuts in the moulding are obviously not possible, but when undercuts are essential in the moulding, split moulds, in which the lower part is made in two sections and can be pulled apart sideways, are employed. Alternatively, side ram presses produce the same effect. The sizes and capacities of presses vary greatly, the small type being capable of exerting a total of 50 tons pressure and very large ones 3,000 tons, used for making radio cabinets and motor-car facia boards. The largest mouldings ever made are believed to be the coffins made by the Ultralite Casket Co. of Stalybridge, England. The amount of moulding powder used in these compression mouldings is over 90 lb. without the lid.

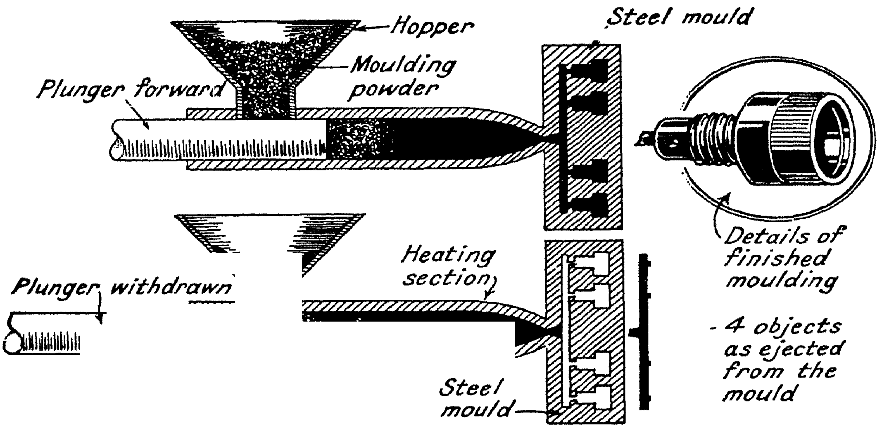
An interesting development in compression moulding that has been carried out for many years is the simultaneous incorporation of metal inserts in the moulding. This is of considerable importance in the electrical industry, where, for example, a threaded insert is utilised to receive a screw. Again, for purely decorative purposes, metal filigrees may be placed in the bottom of the die, prior to the addition of the moulding powder, so that the filigree becomes one with the finished moulding.

**Injection Moulding.**—In broad outline, the process of injection moulding, in which the moulding powders are almost universally the thermo-plastics cellulose acetate and polystyrene, consists in softening the powder in a heated cylinder and then forcing the plastic by means of a piston into a cold metal mould that is kept closed during the moulding operation. This pressure by the piston is maintained until solidification takes place in the mould. The piston is then withdrawn, the mould is opened and the finished moulding is ejected. (See illustration page 50.)

The machines can be vertical or horizontal; some are semi-automatic or totally automatic. The advantage of the horizontal type is the ease of feeding and ease of emptying the mou ds. On the other hand, the horizontal press is generally used for the production of smaller moulded objects, while the vertical presses can more readily be worked for mouldings of 4 oz. and over. In this country it is rare to encounter such heavy injection mouldings,

although machines such as the "Lester," which is a horizontal type with a capacity of 12 oz., are now in use in England. They are, however, quite common in the U.S.A. and Germany. In the former country even small facia boards for automobiles have been injected from cellulose acetate. The heaviest injections so far made have been about 12 oz. in weight.

In the horizontal type the mould is almost always a multiple mould, that is, from two to, say, ten complete objects are made at every injection. The fluid plastic enters the mould through a narrow "gate" and spreads through channels to the dies. Thus,

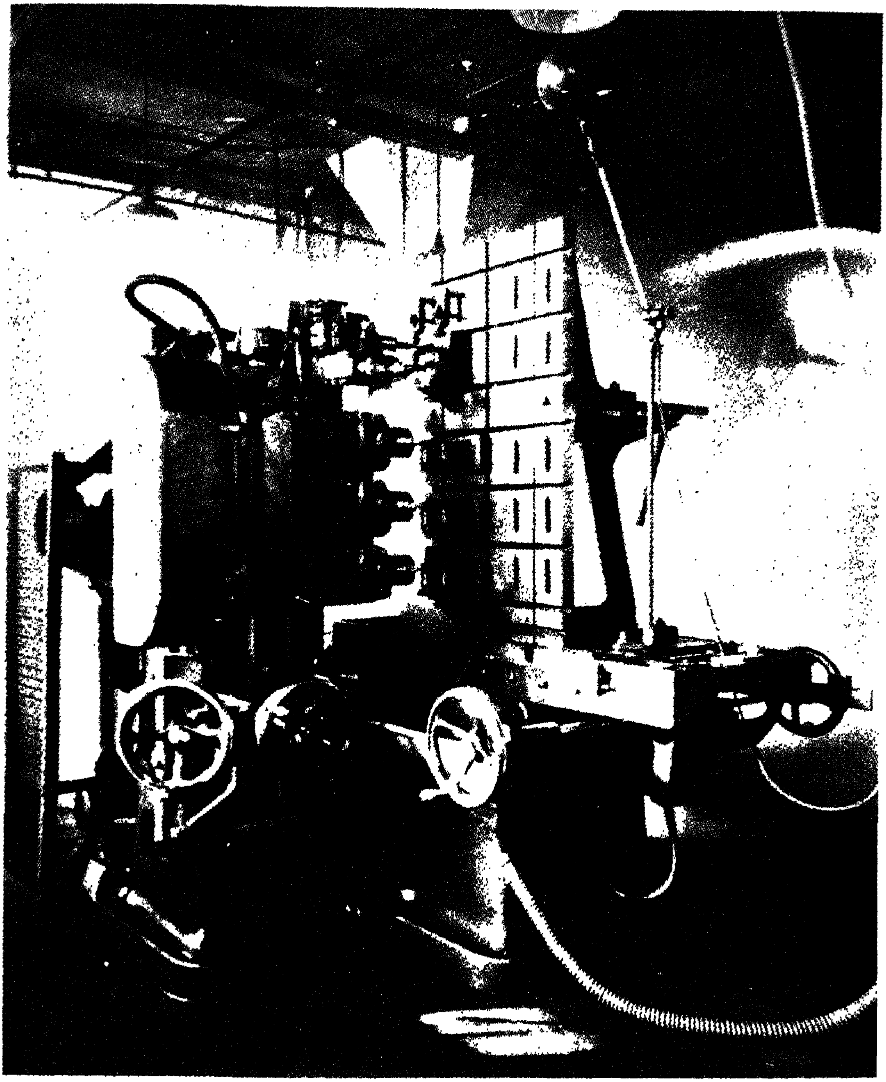



Simple diagram showing essential features of injection moulding.

when the mould is emptied the moulded objects are ejected together because they are connected by a thin strip of plastic. This connecting strip is easily removed and the mouldings need little or no finishing operations.

The ease of operation of these machines and the rapidity of production by them has greatly increased their popularity in the last two years. Assuming an 8-impression mould and a 20-second moulding cycle about 1,400 small mouldings can be produced every hour. To-day, combs, radio-knobs, bottle-closures, coat-hangers, watch-cases, fountain-pens, and a host of other objects are thus being made.

A specialised application of injection moulding that began in



The Keller diesinker produces automatically all kinds of dies.

*(Courtesy : Alfred Herbert, Ltd.)*

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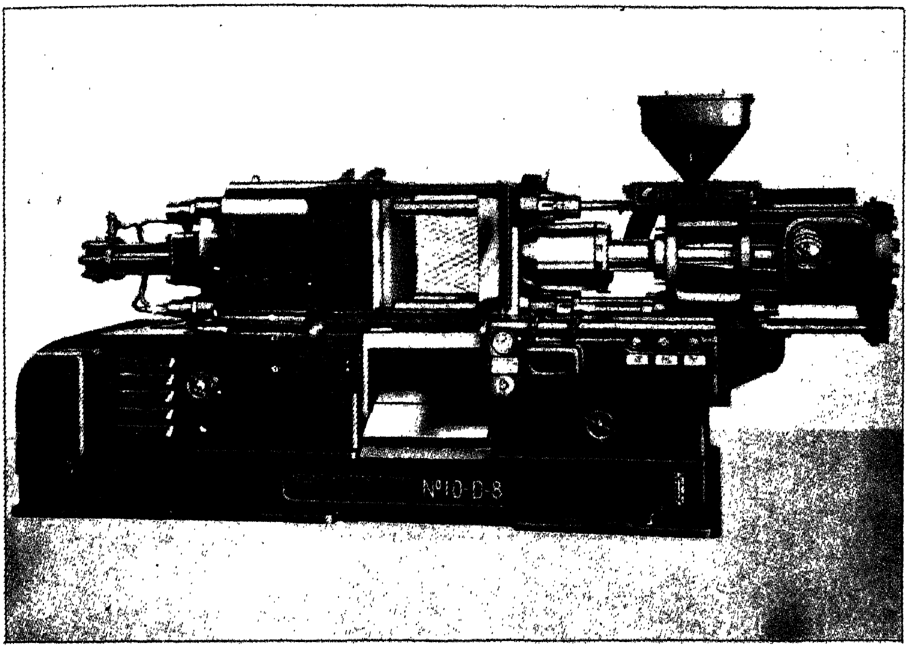
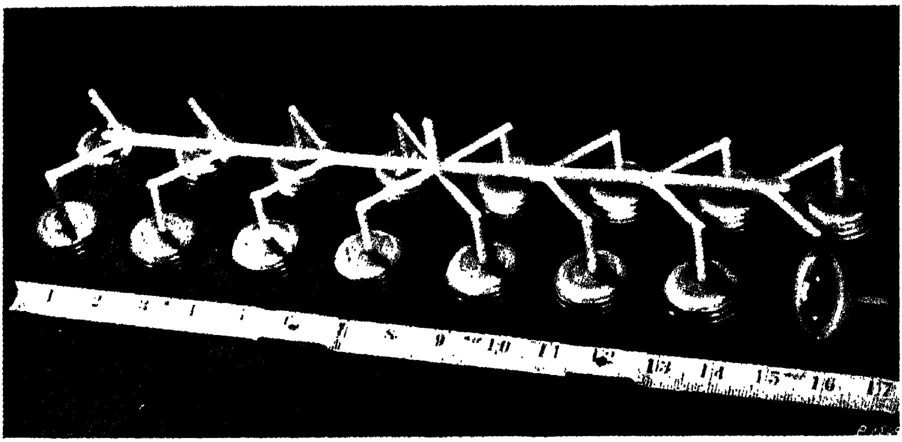
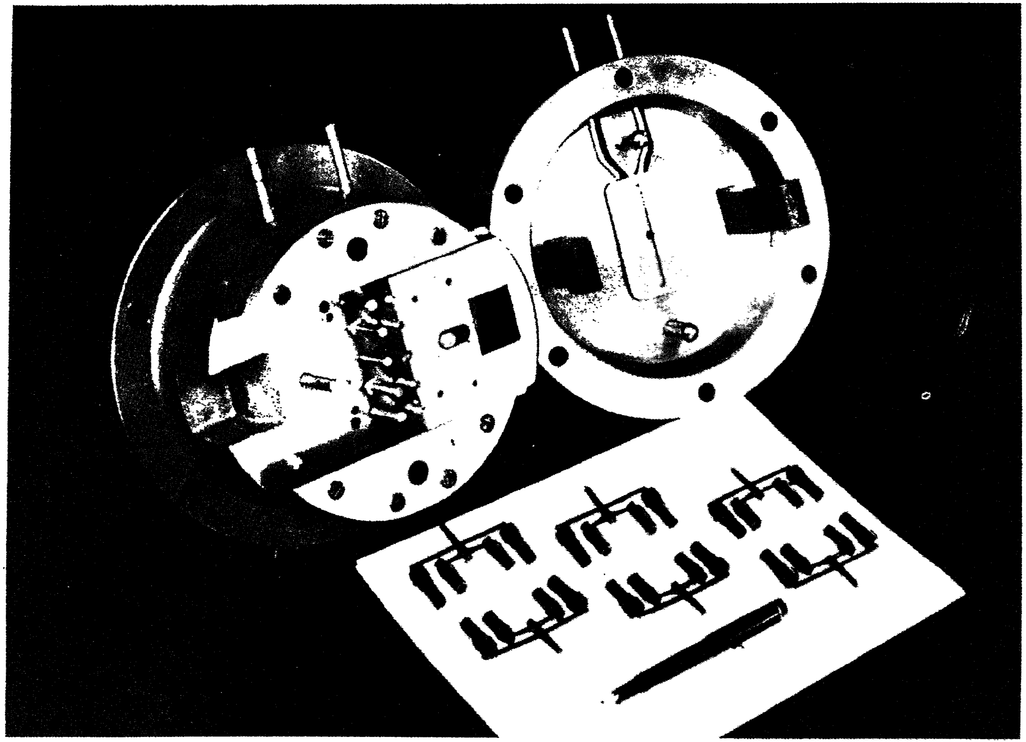


The Reed Prentice injection moulding machine and (below) ferrules for motor-car door and window handles made on it.



Fountain-pen components moulded on the " Isoma " automatic injection machine.

The mould is seen above.

Facing p. 51.]

Australia by Die Casters Ltd. is the injection of cellulose acetate round a metal die casting for the production of high-strength objects. This method has especially been applied to motor-car door-handles, where the all-plastic handle would scarcely have proved satisfactory, unless made of high-shock material.

As we have already indicated, the general practice is to use thermo-plastics in injection moulding. Some workers have successfully employed thermo-setting resins, and claim a great future for them, in the injection moulding of small articles.

## MACHINING OF PLASTICS

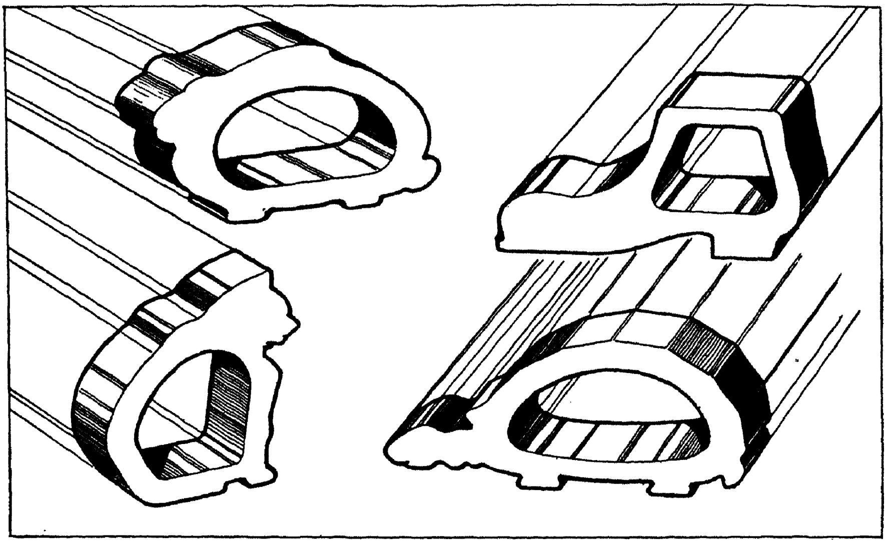
All plastics can be machined although, obviously, some are not amenable to such ready machining as are others. Broadly speaking, the thermo-plastics are simpler to machine than the thermo-setting resins, and in the thermo-setting class those containing no fillers are easier to machine than those containing fillers.

There is no need to stress the point that for injection or compression moulded objects there is no need for after machining, since the moulding, with rare exceptions, is ejected ready for sale. Indeed, the whole conception of the design of the mould is to avoid after finishing and provides holes, threads, etc., already sunk or cut.

Machining, therefore, refers rather to the sheet, block, rod, or tube that is produced in thermo-plastics, in cast and extruded resins or in laminated material.

**Thermo-plastics.**—There is little to add to the notes already given under " Blowing and Forming." All the thermo-plastics can be bevelled with rotary cutters, cut with guillotines, although in very cold weather they should be warmed slightly, punched and sawn by standard machines and tools. Circular holes can be drilled with the normal twist drill, but if thick sheets are used warming is again advisable. Filing, profiling and turning is carried out in the same manner as with wood. Casein and acrylic resins in sheet, block or rod form are especially suitable for this treatment, and wonderfully colourful or transparent objects of high artistic merit are thereby produced from them. Especial reference must be made to the great merit of acrylic resin. The sheet cuts as easily as ivory and is especially amenable to the art of turning. The remarkable optical properties of this plastic provide very pleasing effects when the surface is cut.

**Cast Resins.**—The principle forms that are usually machined are the cast and extruded shapes, the former without filler and the latter with filler. The cast resins are supplied to customers in the fancy goods, cutlery and allied trades as extruded rods and tubes, which resemble the finished article in which the material reaches the market as closely as is convenient. Thus, manufacturers of " draughts " or " chequers " receive cylindrical rods which can be sliced and turned without much loss of material.



Profiled cast resin tubular shapes sliced to make table-napkin rings of interesting designs.

On the other hand, castings may be made to the customers' own designs. This form is readily seen, for example, in the accompanying simple design for children's table-napkin rings in the form of a rabbit, etc. The casting is merely sliced into 1-in. lengths, a hole is bored for the eye and the ring is finally polished.

Cast sheet may be sawn by circular or the band type, the teeth of which must be set for proper clearance and run at a speed of 1,200 ft. per minute. The band type is commonly used for cutting out letters and similar fretwork. In turning operations on rod and tube, high-speed tools are economical and best for long runs,

Knife-handles, tube and spherical display fabricated from Catalin cast resin.

[*Facing p.* 52.

but standard tools may be employed. Rods and sheet may be tapped, but it is best to work with coarse threads.

On the whole, the machining properties resemble those of hard wood or brass. Any type of saw can be used, and suitable drills are those used for brass. In turning and milling operations the same feed and speed as in turning hard wood are employed. Cast resins always need polishing to bring out the best results. The standard buffing wheel can be used, but for small objects, such as jewellery, tumbling in pumice and then damp hard wood sawdust is more convenient and very efficient. A final polish can be given by tumbling with clean shoe pegs and a wax compound.

**Extruded Phenol-Formaldehyde Resins.**—It is rare that any machining or finishing is carried out on extruded plastics other than a simple sawing into standard lengths. The industry of extruded plastics, as we have already pointed out, is not yet widespread, but the concerns that employ them have gained considerable information regarding their machining. In the production of duplicator rollers, for instance, Gestetner Ltd. grind the outer surface and polish to the perfect condition required for the job. The inside rims at the two ends are then bored to a short depth to receive two moulded closing " ends." In the early days it was considered impossible to bore this material, but the process is now quite efficiently done by using " Wimit " tools.

**Laminated Materials.**—Laminated plastics reach the customer in the form of sheet of varying thicknesses, blocks, rods and tubes to be machined into components for the electrical and engineering industry.

Punching is readily carried out on all types of laminated material. Thin sheets of the order of $\frac{1}{32}$ in. can be punched cold, but should be heated for greater thicknesses. Small gears for gramophones are thus produced by the strip.

One of the most interesting industrial developments of this material is the production of silent gears from very thick sheet or block. The sheet is first cut into circular gear blanks by means of a band saw or by trepanning. The teeth are then cut by any of the standard methods and machines—milling machines, gear cutters, and shapers. All the manufacturers of the raw material issue comprehensive instructions as to feeds and speeds for ensuring the best results and obtaining fine accuracy.

Generally speaking, there is no difficulty in carrying out any

of the usual machining operations with the well-known types of machines. The material can be drilled accurately, milled and shaved, countersunk, turned, tapped, and screw-cut with tools of high-speed tool steel or of the Widia type.

## CHAPTER V

# ENGINEERING AND CHEMICAL MACHINERY AND PLANT

In no other industry has the entry of plastics been watched with more anxiety and hope than in the field of engineering. The reason is not far to seek, for not only was the engineering world up to the 1920's concerned in practice and in thought with metals as almost the only possible materials of construction, but also because any non-metallic substance that did obtain a foothold in this stronghold of metal tradition did so in the face of considerable opposition, as a result of prolonged testing under extremely severe conditions and because it was eminently suited for the job. In a very important sense, therefore, the entry of plastics into engineering raises their status to levels higher than they have ever reached and holds out much of still greater promise as and when the special properties are realised and appreciated.

### LAMINATED AND ALLIED MATERIALS

It was probably only about fifteen years ago that the first steps to present a reasonably strong plastic material to the industry were taken. The early specimens of impregnated laminated materials had been examined and were full of promise for at least one important branch—the production of gear-wheels, pinions and the like, for such preliminary examination indicated a silent gear more lasting than the old raw-hide type. The first laminated materials were of compressed resin impregnated paper, but although extremely promising, they failed because of rapid wear of the gear-teeth. The complete solution was found by replacing paper with fabric, which gave the needed toughness under load.

**Gears.**—The raw material for the production of gears is in the form of a block or sheet (varying from $\frac{1}{64}$ in. to 5 in. thick) made by the cohesion under high pressure and heat of sheets of resin impregnated fabric. This fabric may be a strong cotton duck

or canvas for heavy duty gears and pinions or a finely woven cotton of very light weight for making the small gears used for gramophones or electric clocks.

There has now been made available a wide range of gears, with complete success, ranging from thin and small gear-wheels up to sizes as large as 5 ft. in diameter and 10 in. thick for especially heavy machines. A welcome property of the laminated fabric is the comparative ease with which it can be treated by the usual operations of sawing with band saws or trepanning tools and cut and otherwise worked by turning, drilling, milling and shaving. Spur, bevel and helical gears are all types of common production.

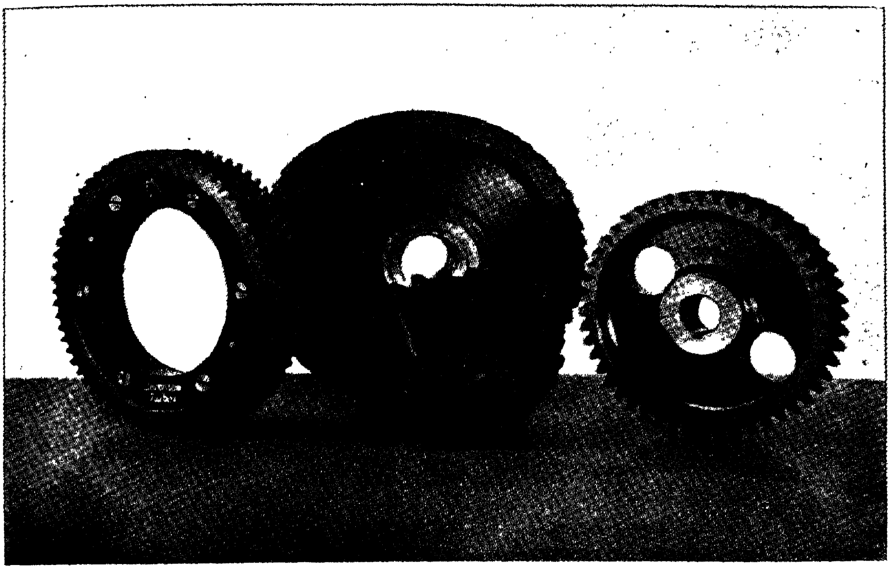
To sum up, the properties of the laminated gear that make it superior to the metallic type are:

1. Silent in action.
2. High strength per weight ratio.
3. Low modulus of elasticity (about 50,000 lb. per sq. in.), making it many times more resilient than steel. Laminated material can thus absorb shocks and intermittent stresses which can break down metal gears.
4. It is stable under all working conditions and resists the action of oils and many acids and alkalis.
5. Will not score metals.

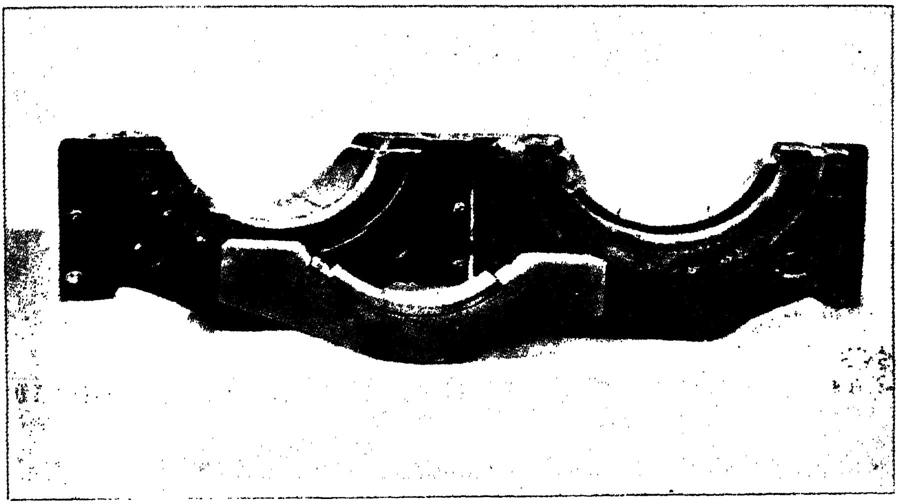
In actual works practice the above advantages have been fully proved over many years' service. The gears are really silent and can allow of the disposition of heavy machinery in places where noisy machinery cannot be allowed. There is the added advantage of having no deleterious effect on the actual workers because of excessive noise. They outlast metal and rawhide gears, need no lubrication, except the rare application of a little graphitic oil, and, finally, the resistance to shock adds longer life to the machines themselves.

It is important to note at this point that such gears (although not very large sizes) can also be moulded in high-pressure moulds, thus avoiding all cutting operations. The raw material for such production is either a flake or "chopped" form of the impregnated fabric, or yet another moulding material made by impregnating flock with an emulsion of phenol-formaldehyde resin. Both moulding compounds are made into extremely tough gears.

**Bearings.**—The production of bearings for light and heavy



Gear wheels fabricated from resin impregnated fabric (Turbox).



Close-up of laminated bearings as used in steel rolling-mills.

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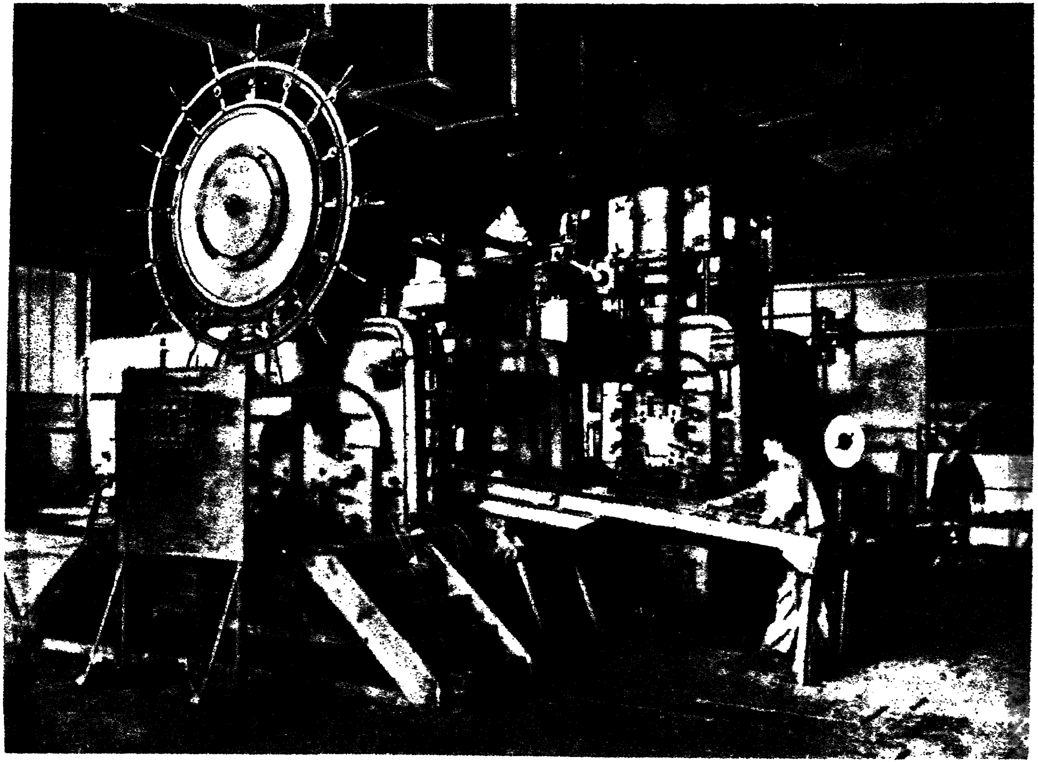


These steel rolling-mills are fitted with roll-neck bearings made of laminated fabric (Demag).

*Facing p.* 57.]

machinery followed soon after the success of the plastic gears, for the qualities required in the one are similar to those required in the other. The raw material for these bearings is practically the same as that used for gears, namely, the formation of a solid block by the compression under heat of resin impregnated fabric, or the flake form for moulding purposes made by the reduction of impregnated fabric into small pieces.

A good example of the mechanical properties of a well-known laminated bearing material is as follows :

| | |
|---|---|
| Specific gravity | |
| Tensile strength | 7,500/8,000 lb. per sq. in. |
| Resistance to bending | |
| (*a*) Vertical to laminations | over 16,000 ,, ,, ,, ,, |
| (*b*) Parallel with laminations | |
| Compression strength (vertical to laminations) | 41,000 |
| Modulus of elasticity | 75,000 |
| Brinell hardness | 40 |

It is stated that the flake material mentioned above, although giving slightly lower figures in mechanical tests, provides a finished product with a coefficient of friction much lower than that of the laminated material. Bearings have been made from the moulded flake material with a backing reinforced by laminated sheet.

As with the silent gears, the bearings run with little or no lubrication. In practice, the lubrication is generally made by water. Thus, not only is there a great saving in lubrication costs, but the water serves to cool the bearing, which, because of its low heat conductivity, would otherwise tend to heat up.

Indeed, heat conductivity and frictional resistance are the most important features of a bearing and, since the application of a lubricant, such as water, readily absorbs the heat generated in the plastic bearing and, since, also, the coefficient of friction is very low, especially at low speeds, the new bearings approach the ideal for metal rolling mills.

To sum up, the advantages of the resin impregnated laminated bearing are :

1. Low coefficient of friction. One published test showed that, using water as lubricant, it is about $\frac{1}{4}$ to $\frac{1}{3}$ that of the coefficient of friction of an oil-lubricated white

metal bearing, under running conditions of 400 ft. per minute and 500 lb. per projected sq. in. of projected surface.

2. Reduction in power consumption and in time, due not only to above in normal running, but also in starting up from the cold.
3. No tendency to score the shaft, rolls run smoother, and there is less necessity to adjust rolls due to wear.
4. This, in turn, gives greater regularity of product, and absence of oil gives a cleaner product.
5. Plastic bearings last three to four times as long as bronze bearings.
6. They are unaffected by acid atmospheres and cannot rust in humid atmospheres.

The foregoing properties, especially resistance to wear, oils, greases and solvents, and the ability to dampen vibration and shock, make the same material attractive for many other engineering components. It is eminently suitable, for example, on flexible couplings to relieve end thrust and is so widely employed in the U.S.A. The same product, in the form of moulded rods, makes excellent drive or shear pins which, on shearing on overload, do no damage to metal parts since they are non-scoring. *Modern Plastics*, October, 1938, p. 262, describes the value of laminated impregnated fabric in a new mechanical application because of its high resistance to temperature changes. In casting inserts into iron or steel it is necessary that the inserts be held rigidly and accurately in position during the core baking and casting cycles. Plate- or tube-laminated material is machined to support and locate the inserts properly, while the core is formed and baked and becomes an integral part of the core as it is placed in the mould. Thus, the inserts cannot be displaced and ensure a perfect moulding.

Suction-box covers of great length, on foudrinier and other paper plant, have long been employed, replacing and outlasting wood in a water-laden machine.

A host of smaller units made of fabric base find employment in a diversity of fields—as oil-pump gears, thrust washers, gaskets, pump vanes, ball-bearing retainers, thrust collars, truck wheels, picking sticks for textile looms, friction cone heads, doctor blades

on paper-feeding and similar machines where metal should be avoided, owing to danger of spoilage of the manufactured goods by rust.

Another form of laminated product, that made up of laminations of wood, should be especially attractive to the engineering world, although its applications outside the electrical and aircraft industry have been limited. Most of the industrial countries make this type, some of the best known appearing under the trade names of Permali (English), Jicwood (English), Jabroc (English), Permali and Durisol (French), Lignostone (German), etc.

The methods of manufacture differ slightly. In some instances the thin sheets of seasoned wood ($\frac{14}{1000}$ in. and upwards in thickness) are merely coated with a synthetic resin solution and then compressed under heat; in others, layers of Plybond or Tego film (resin-impregnated tissue paper) are placed between the sheets of wood and compressed; or, yet again, a third method, for example that adopted in making Permali, the sheets are impregnated under pressure with an alcoholic solution of resin, solvent is removed under vacuum and a number are compressed and heated under high pressure. Whatever the process, however, the finished material appears as a sheet or block—hard, acid-resisting, non-warping, of great mechanical strength and excellent dielectric properties. Blocks 10 in. thick have been produced. Moreover, within limits, the impregnated sheets can be moulded into slightly curved or other simple shapes. As indicated on page 86 such material is widely used for the construction of electrical components, such as busbars, transformer rings, insulating fish plates, radio insulators, transmission line cross-arms, core side plates, core wedges, and many different types of electrical machinery. In addition, aeroplane propellers are built, and boats, especially of the kayak or canoe type, have formed an important outlet for the material. Yet another interesting development, although not yet apparently a commercial success, was the building of barrels for holding corrosive liquids and salts. Apparently the industry concerned in buying such containers are loath to adopt them, at present, but we hope that interest in them will not disappear altogether, for we regard such acid-resisting barrels a logical replacement of lined barrels and kegs, some of which are not so successful as they might be.

The first application of laminated and impregnated wood in

the engineering world, outside the electrical field, we have encountered is also perhaps the largest ever made. It is a mortar built up from Permali, made by the French concern, for the mixing of dynamite, and consists of a very solid circular structure in trough form to allow mixing of keiselguhr and nitroglycerine by rotating rollers. So new is this application that details are lacking, but presumably a strong acid-resisting material, resistant to abrasion, non-metallic and non-sparking was required. In size it is impressive, being about 12 ft. in diameter and 24 in. high.

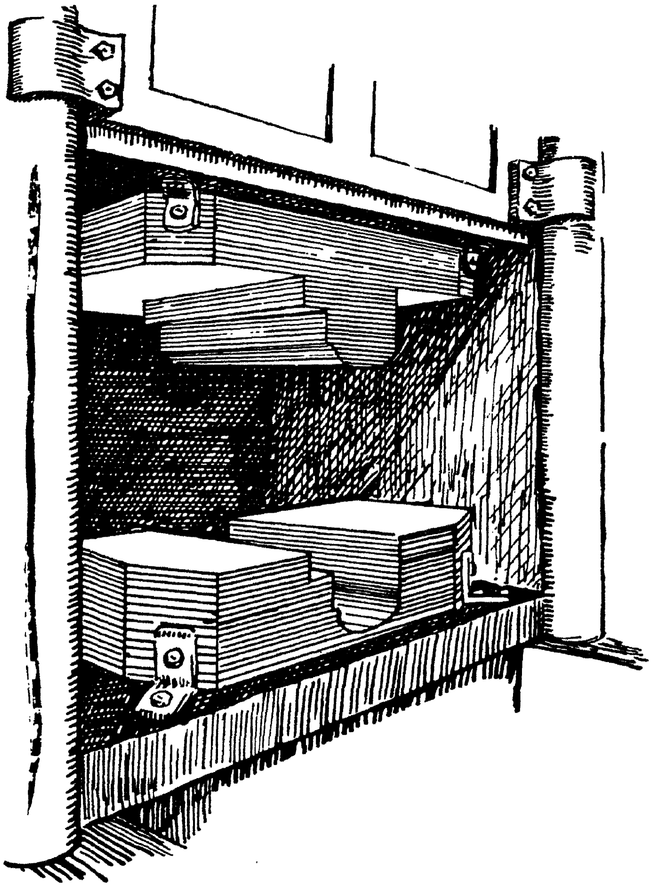
It is not difficult to imagine that impregnated and compressed wood is, as corollary to the airscrew, perfectly suitable for the fabrication of the large type of air-extractor fan utilised in coal-mines, gasworks and the like. They are now widely employed where oil- or acid-laden gases must be extracted for washing or other purposes. Their non-sparking properties make them especially attractive.

Of comparatively recent interest is the use of resin-impregnated wood for making press tools instead of heavy metal castings which can only be machined with difficulty. The advantages claimed for the resin-impregnated wood (Jabroc) may be summarised as follows :

1. Ease and rapidity of machining on standard lathes.
2. Adaptability to series production in aircraft manufacture which usually entails modification of the design at least once before actual production is put in hand.
3. Lightness in weight. This is considerable as the specific gravity is only 1·3 to 1·4, that is, about $\frac{1}{5}$ to $\frac{1}{6}$ that of steel. Lightness in weight facilitates handling and setting up of machines and so increases the tempo of production.

Stamping tools fabricated of resin-impregnated wood are now in regular use in aircraft factories for turning out aluminium, aluminium alloy and steel sheet pressings and they have an average life of approximately 2,000 to 2,500. When the tools show signs of wear they can, of course, be built up and re-used. In spite, therefore, of the relatively high cost of this non-metallic material when compared with steel, its working properties are such that considerable economies can be practised in the works and its use facilitates increased production. Resin-impregnated wood

tools are particularly suitable for rearmament work where speed is of the utmost importance.



Press tools made of Jabroc, resin-impregnated wood.

## CHEMICAL PLANT

By far the most important engineering constructional work in synthetic resin materials has taken place in the chemical and allied industries. This is due, first, to the fact that, more than any other, the chemical industry is so much concerned with the effects

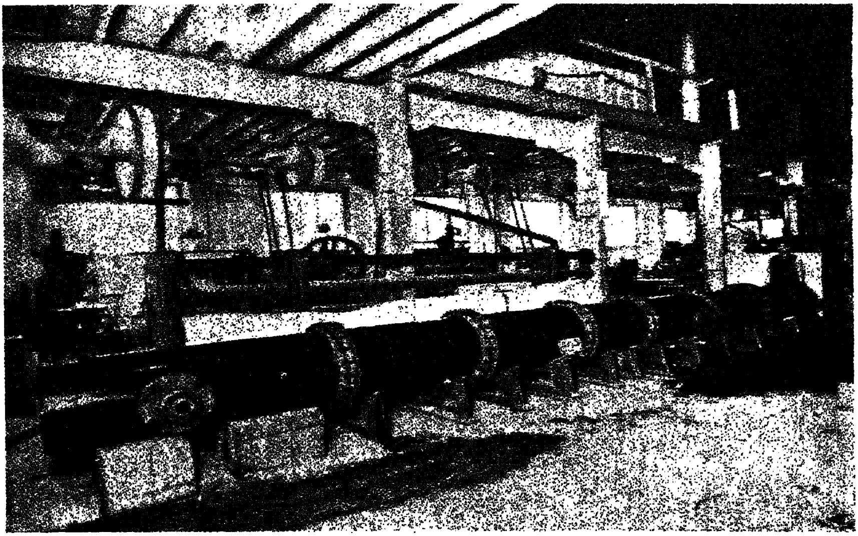
of corrosion and, secondly, as a result of the first, the chemist is more ready to examine new materials of construction than the engineer, who rarely deals with corrosion problems other than simple rusting.

Chemical manufacture entails a host of chemical engineering processes—storage and pumping, distillation, evaporation, heating in open or enclosed vats, drying, filtration, washing or extraction in towers, etc. etc., and utilises concentrated and weak acids both inorganic and organic, alkalis, salts, organic solvents, etc., and, to fight corrosion against these, special metals such as platinum, gold, silver, stainless steel, lead, copper, aluminium, silicon iron, earthenware and fused silica, glass linings, rubber and wood have long been employed. Many of these have serious drawbacks, such as cost in the case of the first four named above, brittleness in the case of silicon iron, earthenware and fused silica, the disadvantage of imparting impurities by some and the limited corrosion resistance of others.

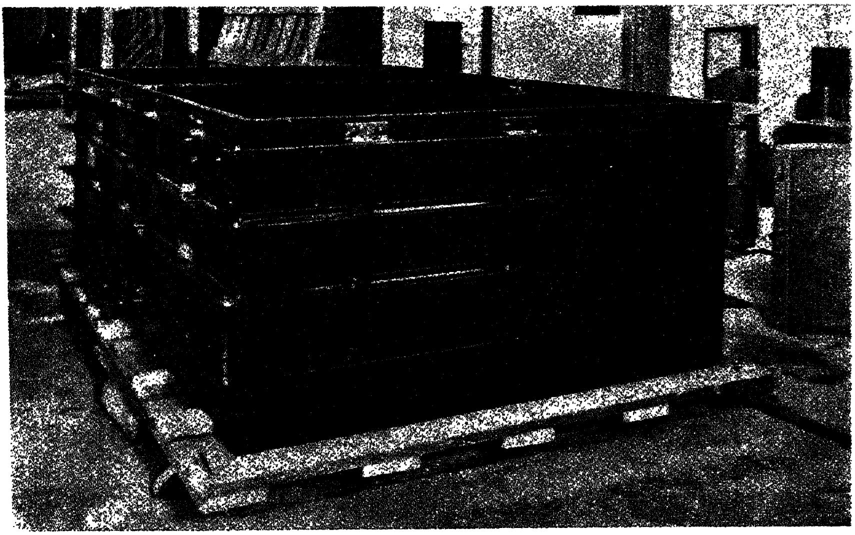
Although the important corrosion-resisting properties of phenolic resins have been known since their inception, the application had been limited because of the difficulty of making the large structures necessary, the normal method of moulding in expensive moulds being quite out of the question, since repetition work in the chemical industry is comparatively unknown—the size of two tanks, for example, is rarely the same. It was only until the stage of utilising simple and inexpensive moulds was arrived at did the construction of single pieces become economically possible.

To-day three important concerns are carrying out the construction of a large range of plant from mixtures of phenolic resins with fillers, generally carefully selected asbestos fibre. They are Kestner Evaporator & Engineering Co. Ltd., London, who produce the finished plant of the plastic known as Keebush, the Saureschutz G.m.b.H. of Berlin, Germany, who make it of Haveg and the Haveg Corporation of Newark, Del., U.S.A. The raw material and methods of construction are probably the same in all three companies.

Although actual details of production are lacking, it seems probable that the mass of resin-impregnated asbestos material is first made into sheets or slabs, which are then lined into a simple mould, such as a tank. Heating converts the material into the



Absorption tower 35 ft. high of Keebush resin.
Constructed in 5 sections and fitted with Keebush sprays, grid-plates, etc.



Large two-chambered acid tank constructed of Keebush.
(*Photos by permission of Kestner Evaporator & Eng. Co.*)

[*Facing p.* 62.

hard and tough finished form and it is then separated from the mould. In the case of a pipe, the sheets are wound round a removable mandrel which can be heated to effect the curing of the resin and then withdrawn.

The extent to which Keebush and Haveg have been accepted by the chemical industry is reflected in the very varied type of plant that has been made. Cylindrical tanks for storing acid up to 10 ft. diameter by 10 ft. deep and of wall thickness $\frac{3}{4}$ in. have been made, moulded in one piece. This means a capacity of nearly 5,000 gallons (20 tons of hydrochloric acid). Such a tank is sufficiently strong and needs no reinforcement. Larger tanks are provided with exterior steel bands or wooden holding structures. Towers for washing gases have been produced in sections and assembled by split metal rings. Such structures, with bottom inlet pipe and top exit pipe and fitted with perforated shelves to hold the packing units, have been built 3 ft. in diameter and 10 ft. high. Pumps, agitators, fans, crystallising pans, drying trays, filter press plates, steam injectors, pickling tanks, dye vats, low temperature stills, buckets, pipes, bends, bolts, etc., are now being used industrially.

The literature supplied by the Kestner Evaporator & Engineering Co. Ltd. states that Keebush is especially resistant to:

*Acids and Salts.*—Hydrochloric acid, all strengths; sulphuric acid up to 50 per cent., sulphurous acid, all organic acids, iron, aluminium and zinc chlorides. A special grade withstands hydrofluoric acid.

*Alkalis.*—Ammonia, lime, sodium carbonate, neutral soap solutions. The special grade referred to above withstands caustic soda and potash.

*Solvents.*—Hydrocarbons, alcohol, carbon tetrachloride, etc.

*General.*—Chlorine, sulphuretted hydrogen, hydrogen peroxide, aluminium sulphate, ammonium sulphate, etc.

It does not withstand the strong oxidising acids, nitric, chromic and concentrated sulphuric.

Equally important are the physical properties. For Haveg the compression strength is about 5·2 tons per sq. in. and the bending strength about 2·8 tons per sq. in. About $\frac{1}{5}$ the weight of steel, the material provides saving from the point of view of installation, holding and supporting structures. It has a homo-

geneous, smooth and impervious structure, so that cleaning and maintenance is simple. It readily withstands sudden change in temperature (the upper temperature limit of normal working is about 130–140° C.), a property not possessed generally by glass-lined or silica vessels.

As for the important question of length of life of plant made from these plastics, it is interesting to note that some of the earliest applications were in the form of metal pickling tanks which have been in use for more than ten years and are still working without trouble. Large and complicated pickling tanks, some 60 ft. long and fitted with inlets for acids, steam, water and compressed air for agitation, have been constructed completely of this type of synthetic resin. The makers claim that in certain instances the efficiency of pickling plant has been increased by 100 per cent. and more.

In addition to the moulding or building of solid structures, Haveg and Keebush are both available also in the form of a cold setting plastic which can be used by the worker on the site to patch repairs, to set tiles, to make joints and so on. The asbestos-resin compound is mixed on the spot with an alcoholic solution of sulphuric acid and is worked with a trowel as with ordinary cement. It soon hardens and becomes quite insoluble.

**Dekorit.**—Yet another form of solid resin structure that has recently appeared in chemical engineering is the cast moulding. As described in a previous chapter (p. 20), liquid phenol-formaldehyde resin, without fillers, can be poured into simple moulds of lead or glass and when cured, usually after several days, or even weeks, at a controlled temperature, are removed in the solid form. Thus a rod or tube or other simple shape is made, which can be readily cut into slices, short tubes, cubes, etc., according to the profile. Manufacture was until recently confined almost solely to producing small parts for the fancy goods and imitation jewellery trade, but an interesting advance has already been made beyond this. The *Queen Elizabeth*, the newest of British transatlantic liners, is fitted with some thousand or so lavatory seats cast in solid resin.

The earlier types of cast resin suffered somewhat from liability to shrink, to gradual change in colour. This was probably due to the difficulty of reaching finality of cure, which normally continues for some period after the casting is removed from the

mould. In addition, although the water absorption is low and quite suitable for normal purposes, it is probably not quite suitable where continual immersion in water or other liquids is required. These drawbacks have until recently held back wider application of cast resins, especially in the engineering industry.

The latest researches, however, have resulted in the production of a much superior cast resin by Chemische Fabrik Dr. Raschig, G.m.b.H., the German chemical concern headed by the well-known chemical engineer who for many years has produced the normal type of phenolic cast resin.

The new resin is called Dekorit F, the following claims being made for it. It is a fully cured material and is thus completely dimensionally stable. It is also free from porosity. It possesses all the advantages of ordinary cast phenolics, being very hard and heat-resistant and, it is claimed, is even somewhat superior to them in these respects. Like all cast resins, it is resistant to all acids, except certain oxidising acids such as nitric, and also resists action by mineral and vegetable oils and weak alkalis. It can be readily machined and cut, the hard alloy tools of the Widia type being most suitable. Thread and grooves are readily produced.

Dekorit is supplied in the form of rods up to 12 in. in diameter, in tubes, sheets and blocks for further manipulation. A cold-setting cement is also available for making joints, etc.

The applications so far appear to be solely in the field of chemical engineering and density meters, ball valves, large pipes for acid work, pistons, plugs for cocks, etc., are in use with considerable success. For example, a ball valve of Dekorit replacing a bronze ball has given good service for several months, with only slight mechanical wear. The usual life of a bronze ball is about 10 days. Pipes withstand pressures below 150 atmospheres, so that they are quite suitable for medium pressures. Like all similar resins, Dekorit has a low impact strength, so that presumably for large castings some kind of protection, such as a wooden housing, is desirable, if the situation of the plant warrants extra care.

## Rubber in the Chemical Industry.

At this point it is important to mention that it is not proposed to describe the use of rubber in the chemical industry. This is somewhat illogical, for rubber is definitely a plastic. The reason is solely due to the fact that rubber has long had its technical

journals and books and the subject has been thoroughly described for many years past. We can merely indicate that it is very widely employed mainly for the lining of hydrochloric acid storage vessels, towers, pickling vats and for the construction of pipes, cocks, buckets, ball-mills, barrels, pumps, centrifuges, fans, etc. Special rubbers are also available for withstanding cold 60–80 per cent. sulphuric and warm 20 per cent. acid ; it is also specified for acetic acid and sometimes phosphoric acid. Nitric acid (except in very low concentrations) attacks rubber rapidly.

The synthetic rubbers and other rubber-like material are not being used to an important extent for these purposes. Natural rubber is so much cheaper and is very efficient.

It is interesting to note that the lining of a reaction vessel for containing nitric acid and nitric acid salts has been carried out this year (1939) in England, using polyvinyl chloride sheet. The rubber-like type was used and is stated to be standing up very well under the oxidising conditions.

**Miscellaneous.**

The problem of piping for special conditions is extremely important to the engineer, so that the news that Mipolam, the German polyvinyl chloride resin, is being so employed is of considerable interest. It has been stated that Mipolam, which can be produced in a soft rubbery or hard horny condition, is utilised to replace lead piping where water is very soft. Since the material is completely inert there is no danger of water contamination and the possibility of lead poisoning is eliminated.

Although, as indicated at the beginning of this chapter that mouldings made from moulding powders have rarely been applied to engineering, yet the following example is of importance, as showing not only possibilities of construction, but the availability of high strength materials in this special branch of the plastics industry. At the famous London store of Harrods Ltd., a new series of escalators were installed early in 1939. Instead of beechwood slats, some 20,000 moulded ones made from a high strength Bakelite moulding powder were installed, fixed to a Bakelite laminated sheet. The slats, moulded with a serrated edge to prevent slipping have shown excellent service.

Transparent plastics may at first sight be considered only suitable for the manufacture of aircraft and for uses in building and

art, but this is far from the truth. Of the transparent thermo-setting variety the urea resins have found some application in electrical spheres as switch covers and distributor covers where their transparency and high dielectric and non-tracking properties are both important, the former in traçing faulty connections easily.

As for the thermo-plastic group, such as the cellulose group (including celluloid) and the "acrylic" resins, these find many interesting applications, although generally of a subsidiary nature. An important use is for protective guards on working machinery to prevent accidents to workers, at the same time allowing for complete visibility. Simple glass sheet is rarely possible, while the stronger wired glass interferes considerably with the view. Cellulose acetate or "acrylic" resin sheet is the most suitable material.

Acrylic resins deserve additional mention since they possess certain characteristics which make them far more valuable for some purposes than the cellulosic bodies. They are not only much more transparent than acetate sheet and even glass, but they have a very low water absorption. Since in addition to sheet they also appear on the market in a granular mouldable form, they have been made into special shapes, such as bulkheads and accumulator boxes, where strength, transparency, water resistance and, in the case of the accumulator box, high resistance to acid, are essential properties. The "acrylic" resins also lend themselves admirably to use as sight glasses of low temperature processes or of the working of delicate instruments.

The rubber-like plastics and synthetic rubbers deserve special mention in this section for they have solved the ever present problem of swelling and solution by oil and grease. Neoprene, the Buna rubbers and Thiokol all find application in the fabrication of gaskets, valve-seat discs, washers, piston plungers, packings and oil-conveying pipes. Thiokol is also available as a moulding powder so that shapes of considerable complexity can be made from it.

The following additional miscellaneous list demonstrates the wide scope which plastics find in engineering:

| | |
|---|---|
| Pulley blocks. | Conveyor chains. |
| Couplings for oil-well instruments. | Bolts and screws. |
| Axle bushings. | Tool handles. |
| Moulded fans. | Abrasive wheels. |

**Further Possibilities and the Works Engineer.**

There is little doubt, we believe, that were every works engineer to look round his own particular works he would find that plastics would solve many of his everyday worries and in many ways improve the efficiency of his plant and the quality of his final product by the installation of some of the components just described.

It is an obvious truism that corrosion and wear takes place in every factory, whether that corrosion is due to normal atmospheric conditions, or to extraordinary acidic or alkaline conditions. It is up to the works engineer to decide whether or no it is worth while installing non-corrosive material, but it is necessary to repeat how serious corrosion can be in factories which are by no stretch of imagination chemical industries.

At first sight it would seem that the food factories of the world should be among the most important users, since freedom from metal contamination and freedom from dirt are prime desiderata in such works. Metal contamination in the sense of the introduction of metal dissolved in foods beyond the permissible limits of food laws is extremely difficult to avoid. Such metal (generally present in the final product in some few parts per million) may be present in the raw materials or dissolved in transit or in treatment from the vessels employed in manufacture. It is not inconceivable that storage tanks, liquor-conveying pipes and certain other plant built of plastics would diminish the danger. Mixing plant employed for " cold " (below 120–130° C.) mixing also seems appropriate. High temperature boiling, such as in jam-making, is not possible with plastic structures.

A metal contamination different from the above also occurs (happily rarely) in food factories. We refer to the accidental occurrence of comparatively large metal pieces—broken bolts, nails, metal wire from filters and so on, which, on occasion, manage to escape the closest care and supervision. Even pieces of glass have been known to appear in the final product. It seems almost humanly impossible to avoid all such occurrences, but in general terms it seems obvious that the inclusion of plastic materials, where possible, should diminish the probability. At least we know of one concern that has installed " acrylic " resin protectors round electric lamps to avoid broken glass falling into food products.

One of the most precious boasts of the twentieth-century food factory is the maintenance of cleanliness, both of personnel and plant. It is natural that the effort should be first applied to the food factory, but the necessity is there in all types of factories, whether they are factories making face powders, glue or photographic material. Purity of product is one of the important advances of this century. But of what avail is a worker working in a beautiful white smock if a rusty leaking water pipe is allowed to drip its red quota of iron oxide into a tub of finished goods, if grime is allowed to accumulate on walls difficult to clean, or if specks of distemper are allowed to float down on filling tables? Such simple protection as plastic-laminated wall panelling may be considered fantastically expensive, but the economic balance sheet against the elimination of yearly painting, ease of cleaning and resultant cleanliness has never, we believe, been made.

In this category must also be included the "mineral water" factory, which often manufactures, in addition to ginger ale, lemonade and the like, squashes of various fruits. The abundance of water, as well as acidic juices, is responsible for extensive corrosion. Pickle factories, too, call for special examination, for vinegar and nearly all condiments have destructive action on metal and wood.

In discussing the structural materials that are used for canning factories, T. W. Jones in a recent paper before the Society of Chemical Industry says:

From the point of view of bacterial contamination, the smooth surfaces of metals give them an advantage over wood which is difficult to clean and can retain enough foodstuff in its grain and cracks to provide excellent breeding ground for micro-organisms of all kinds. In considering the suitable metal, it must be remembered that it has to withstand exacting acid attack, particularly in the handling of fruits and vegetables. Not only are metals required for sorting and picking tables, but also in the construction of the various machines in which the food is prepared, such as blanchers, snibbers, syrup and brine tanks, syrupers, briners and filling plant. Furthermore, a good deal of corrosive fluid is spilt from cans on to conveyor belts. Another point to be considered is the possibility of the setting up of electrolytic couples between different metals in the same machine, whereby corrosion and contamination of the food is possible. This is a point to which far too little attention has been given by plant makers, and it is not unusual to see equipment with three or four different metals in contact one with

the other and all thoroughly wetted with brine, syrup or juice. In apple-canning, iron can be a great nuisance, as an inky black liquid from the tannins in the juice can soon spoil the appearance of blanched apples, and here again, quite unsuspected sites for contamination are frequently found. For example, in an apple pre-heater the belt was made of Monel metal and the drum carrying it was constructed of wood, the shaft of the drum, however, was of steel, and the acid steam condensing on this formed an excellent black liquid which fell on to the belt and was conveyed to the fruit. Corrosion of galvanized iron guides in a conveying system has also caused unpleasant blackening when the zinc surface had corroded sufficiently to permit attack of the iron. Trace quotes the case of copper fingers of apple slicers which produced unpleasant green colorations. He also quotes the case of a syruper in which a Monel metal tank was carried on an iron frame. A green nickel salt was deposited at the point of contact with, once again, damage to the fruit. Pumps can be quite troublesome, and it may sometimes be necessary to replace the metal with lignum vitæ.

It seems strange that the author of the above paper should not have mentioned plastics at all. Sorting and picking tables seem the obvious outlets for laminated and impregnated sheet made from either paper or, better, wood veneers. Conveying systems—rollers, belts, chains—and even pumps of plastics provide a non-metal system of already proved worth.

The same necessity for " looking round " is present in the dry-cleaning industry where special engineering problems exist, since petroleum distillates and other organic solvents, such as trichlorethylene, are employed. Plastics, unattacked by these, should find an outlet in piping and washers. Generally speaking, it would be advisable to avoid corrodible metal in a dry-cleaning industry where cleanliness, especially the avoidance of spoiling cleaned fabric by rust, would appear to be of first importance. Plastic examining tables, hanging racks, etc., have already been suggested as desirable, yet we believe these apparent advantages have nowhere been introduced.

The refrigerator and ice-making industries, especially those that employ brine, suffer greatly from corrosion, not only because of the all-pervading water employed in the manufacture, but also from condensation. Furthermore, brine attacks iron and steel readily. Yet even the well-known rubber pipe for conveying brine is a rarity in small factories and the use of plastic sheet to prevent general contamination almost unknown. It might yet

be discovered that plastics, with their low coefficient of heat transfer, may be useful to prevent leakage of cold at special points.

Another obvious field for plastics would seem to be in factories manufacturing or using distilled water and especially the photographic industry where contamination by very small quantities of metal is fatal to the production of film or photographic chemicals. Normally pure tin piping, glass-lined tanks, porcelain vessels, etc., are employed. High initial cost and maintenance is general, so that the use of plastics is more than attractive here.

It would not be too much to say that there is no works in the country where plastics could not be used with advantage. Intelligent observation and understanding of plastics is all that is required.

**Synthetic Resins for Water Softening.**

Experiments carried out at the Chemical Research Laboratory, Teddington, in 1936 and 1937, by Sir Gilbert Morgan and others showed that certain types of synthetic resin, particularly those made with some of the natural tannins, such as sulphited quebracho, possessed interesting base- and acid-exchange properties, which could be usefully exploited in softening water. Thus a sulphited quebracho formaldehyde resin was found to possess base-exchange properties and a resin made by reacting *m*-phenylenediamine with formaldehyde acid-exchange properties. By using these two different types of resin, the base-exchange first and the acid second, all the temporary and permanent hardness salts can be removed from water.

In addition to the ability of these high molecular resins of softening water at least one of them, the *m*-phenylenediamine resin, has the unique property of being able to remove sodium fluoride from water. This, incidentally, is important as some natural waters are known to contain small quantities of fluoride which is responsible for certain types of dental decay. The main disadvantage of these resin exchanges is that some of them are slightly soluble in water and cannot, therefore, be employed where no organic matter of any kind must be allowed to contaminate the water. It is possible that this is only a temporary setback and that when the range of exchange resins is enlarged some will be found suitable for drinking waters.

A writer in *Chem. Fabrik.*, January 1940, p. 30, gives an inter-

esting account of the use of synthetic resin exchanges for treating highly saline water from the river Saale used for feeding boilers working at 675 lb. per sq. in. The writer summarises the advantages of resin exchanges as follows :

1. A fourfold increase in throughput per unit volume.
2. Lower resistance to flow, enabling deeper exchange-beds to be used, due to the higher efficiency of coarser-grained material.
3. Improved chemical resistance of the resin exchange, which will now function with water up to 9·5 *p*H.
4. Effective softening at higher temperatures.
5. Increased life of the exchanger material.

The writer points out that possibly the greatest advantage is the ability of the resin to be adapted to suit almost any prevailing condition, and this is of considerable importance to both the engineer and chemist.

# CHAPTER VI

## THE ELECTRICAL INDUSTRY

SYNTHETIC resins are now being produced which possess most of the properties required for their successful exploitation in the electrical field.

For general applications, such as switches, plugs, adaptors, lamp-holders, radio and telephone components, magneto and coil parts, meter cases and instrument parts, domestic electrical appliances, etc., phenol-formaldehyde resin powders fulfils most requirements as it is available in the ordinary wood-filled grade, fabric-filled for high impact uses and mineral-filled for high heat resistance, etc. Ordinary grades of phenol-formaldehyde resins can be used for applications where temperatures up to 140° C. are experienced.

The urea-formaldehyde paper- or wood-filled resins find similar applications to the phenolic resins, but they possess the advantage of being available in white and pastel shades, in translucent and opaque colours. They also possess a greater resistance to tracking than the phenolics and are thus extensively employed as switch-bases, which were at one time made of porcelain. On the debit side, however, the urea resins are not suitable for use at temperatures in the vicinity of 100° C. and show a marked decline in electrical properties at elevated temperatures. Their moisture absorption figures are also higher than the phenol-formaldehyde resins.

The cellulose esters possess a high impact strength but only moderately good electrical properties, coupled with a poor resistance to heat. Polystyrol, on the other hand, is mechanically somewhat weaker than cellulose acetate, but its electrical properties are vastly superior and it possesses an extremely low loss factor which is very considerably lower than porcelain. The water absorption figure of this resin is also exceptionally low, but, like cellulose acetate, although rather better in this respect, it is unsuit-

able for use at elevated temperatures, the figure usually specified being about 70° C., that is, some 20° above that of acetate.

Laminated sheet or tube is, on the whole, a material of outstanding value on account of its great mechanical strength, resistance to high temperatures, reasonably low moisture absorption and good electrical properties. This form of plastic is extensively used in the electrical industry for important constructions, such as carbon circuit breakers, linestarters and contactors, instrument panels, switchboards, etc. The advantage of laminated material is that it is very robust and may be machined in the same way as brass with ordinary tools. Generally speaking, the electrical properties of laminated paper are very similar to mouldings of wood-filled phenolic resin, except that the power factor of the laminated sheet is very much lower than the phenolic moulding.

The above remarks are broad and may be considered as being capable of considerable modification. It should be remembered that practically all the different types of plastics are capable of adaptation and the manufacturer can, within reasonable limits, produce a grade to suit most requirements. In many cases the nature of the filler plays a great part in determining the final properties and in others the nature and percentage of plasticiser. Plastic materials are not static and one of their chief advantages is their fluidity and adaptability.

Apart from the use of plastics for the more widely known electrical applications, the newer vinyl polymers and now the ethylene polymers are being extensively used in place of rubber and even lead for special corrosion-resisting cable sheathing. Commercial varieties now being used for this purpose include the mixed vinyl polymers, such as Koroseal, Mipolam, Igelit and the new I.C.I. polymer, Polythene. These new sheathing materials can be readily extruded and are highly resistant to oxidation and oil.

The table opposite, giving the most important electrical properties of the different types of plastics now available for the electrical goods manufacturer, shows at a glance the main differences between the various synthetic resins.

**Phenol-Formaldehyde Mouldings.**

For the majority of electrical applications demanding a material possessing good mechanical strength, electric strength and insula-

| Type of Resin. | Specific Gravity. | Moisture Absorption (24 hrs.). | Volume Resistivity (cm. cube, million ohms). | Dielectric Strength (60 cycles). | Dielectric Constant (60 cycles). | Dielectric Constant ($10^6$ cycles). | Power Factor (60 cycles). | Power Factor ($10^6$ cycles). |
|---|---|---|---|---|---|---|---|---|
| Wood-flour-filled phenolic resin . . . . . . | 1·34–1·52 | 0·2–0·6 | 10–12 | 300–500 | 5–12 | 4·5–8 | 0·040–0·300 | 0·035–0·1 |
| Fabric-filled phenolic resin | 1·37–1·40 | 1·0–1·3 | 9–11 | 300–450 | 5–10 | 4·5–6 | 0·080–0·300 | 0·04 –0·1 |
| Mineral-filled phenolic resin . . . . . . | 1·70–2·09 | 0·01–0·3 | 9–10 | 250–400 | 5–20 | 4·5–20 | 0·100–0·300 | 0·005–0·1 |
| Laminated phenol resin | 1·34–1·55 | 0·5 | 10–13 | 150–1,300 | 4·4–6·5 | 3·6–7 | | 0·02 –0·08 |
| Urea paper filled . . . | 1·48–1·50 | 1·0–2·0 | 13 | 300–400 | 6·6 | 6 | 0·034– | 0·01 –0·03 |
| Cast phenolic resin . . | 1·27–1·32 | 0·01–0·5 | 9–14 | 300–450 | 5–10 | 5–7 | 0·025 | 0·01 –0·045 |
| Acetate . . . . . . | 1·27–1·63 | 2·8–3·0 | 12 | 800–850 | 5·8–6 | 4·4–4·6 | 0·042–0·058 | 0·038–0·042 |
| Vinyl . . . . . . . | 1·34 | 0·05–0·15 | 14 | 600–700 | | 4 | | 0·0175– |
| Acrylate . . . . . . | 1·18 | 0·3 | 15 | 480 | 4–6 | 2·8 | 0·060–0·080 | 0·02 |
| Styrene . . . . . . | 1·06 | 0·00 | 18 | 500–700 | 2·6– | 2·6 | 0·0003 | 0·0001 |
| Hard rubber . . . . | 1·12–1·80 | 0·02 | 12–15 | 250–900 | 2·8 | 3 | | 003–0·008 |

Physical Properties of Chief Plastics.

tion resistance coupled with low moisture absorption and good dimensional stability, phenolic mouldings are in every way suitable for use up to about 140° C. They do not, however, except in very special grades, possess complete freedom from "tracking," especially under damp or humid conditions, nor are they suitable for high-frequency radio and short-wave work where ceramics and, lately, the polystyrols are used on account of their extremely low loss factor.

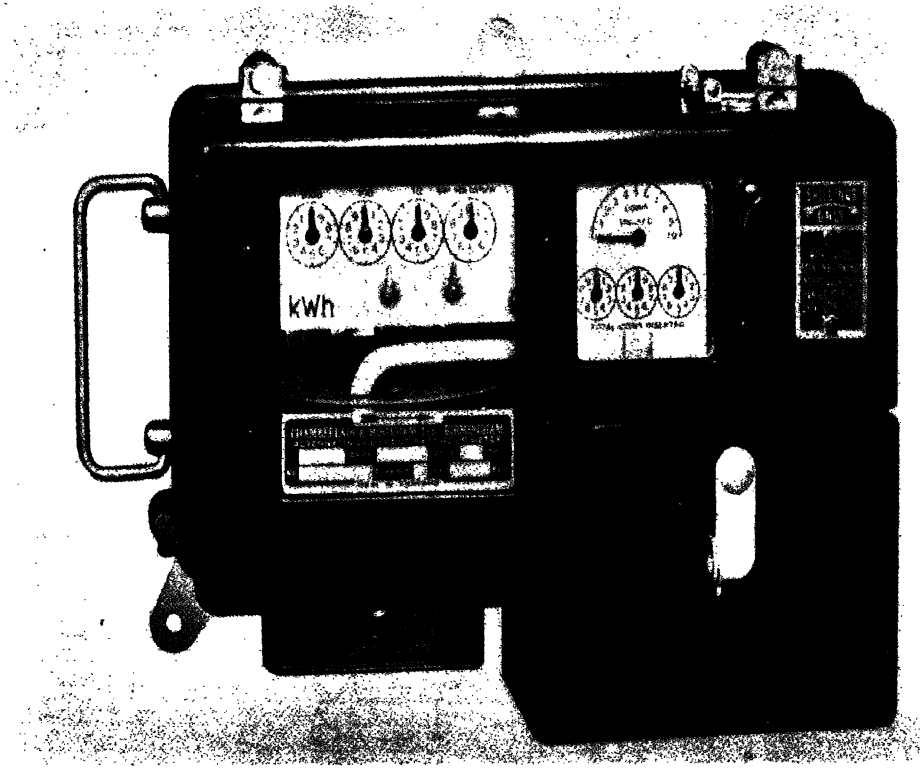
Phenol-formaldehyde mouldings offer many advantages to the electrical manufacturer, apart from those mentioned above. These advantages may be briefly summarised as follows:

1. Available on a mass-production scale in shapes and sizes normally difficult and expensive to fabricate in any other dielectric.
2. Mouldings can be produced complete with metal inserts and with insertions for screws, bolts, etc., ready for quick and labour-saving assembly.
3. Mouldings available at reasonably high degree of accuracy; plus or minus $\frac{2}{1000}$ in. is not uncommon with moulders specialising in electrical goods.
4. When taken from the press the mouldings require very little finishing. The flash has to be removed and perhaps the edges filed.
5. Phenolic moulding powder is very adaptable and grades are available to suit most special requirements. There is, for instance, the standard wood-flour-filled grade for the general run of mouldings, fabric-filled grade for high impact strength mouldings and mineral-filled for high heat resistance and very low moisture absorption.

The field of phenol-formaldehyde mouldings is broadly covered by B.S.S. 771 and deals with five types or grades of material:

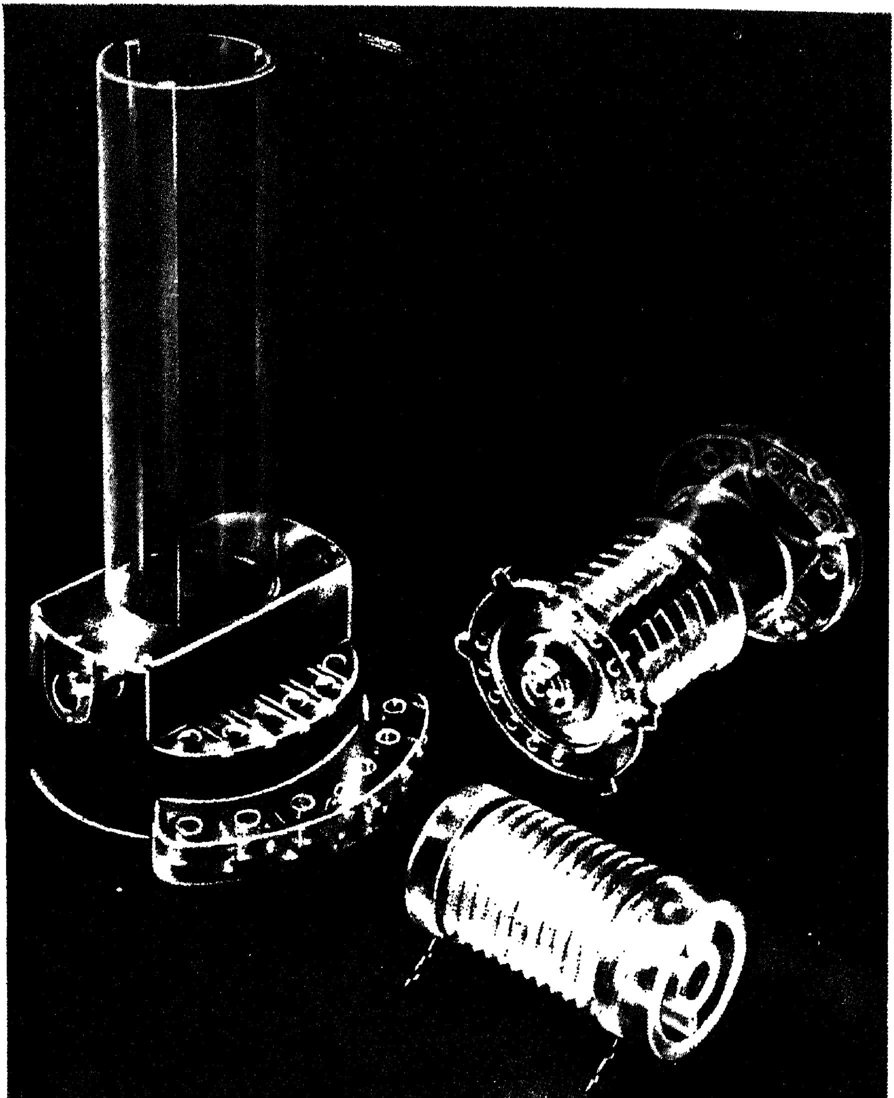
| | |
|---|---|
| Type G | General type |
| Type GX | Improved general type |
| Type MS | Medium shock-resistant type |
| Type HS | High shock-resistant type |
| Type HR | Heat-resistant type |

Although no mention is made of fillers, presumably Type G and




An excellent example of a complicated moulding: meter-case made for Chamberlain & Hookham Ltd., Birmingham.

[Facing p. 76.



Electrical components moulded by the injection process from polystyrene.

*Facing p.* 77.]

GX are wood filled, MS and HS fabric filled and HR asbestos or mica filled.

The following standards are given in B.S.S. 771:

| Test. | Appendix. | Type. | | | | |
|---|---|---|---|---|---|---|
| | | G. | GX. | MS. | HS. | HR. |
| Ultimate tensile strength (lb. per sq. in.) | C | 5,000 | 7,000 | 6,000 | 6,000 | 3,500 |
| Impact strength (ft.-lb.) | D | 0·11 | 0·13 | 0·30 | 0·90 | 0·07 |
| Water absorption (mg.) | E | 200 | 120 | 300 | 350 | 100 |
| Swelling after immersion in water (in.) | E | 0·003 | 0·003 | 0·006 | 0·010 | 0·002 |
| Plastic yield | F | 5 mm. at 100° C. | 5 mm. at 140° C. | 5 mm. at 100° C. | 5 mm. at 100° C. | 5 mm. at 180° C. |
| Electric strength at 90° C. (volts per mil.) | G | 20 | 60 | 20 | 20 | 20 |
| Surface resistivity after immersion in water (megohms) | H | 100 | 1,000 | 100 | 100 | 100 |
| Resistance to crushing after heating (lb.) | J | — | — | — | — | 500 |

B.S.S. 771 states that all mouldings shall be free from porosity, blisters or gas pockets and a cut section shall have a homogeneous texture on visual examination. The specification also states that the density of a moulding free from metal inserts shall not differ by more than 6 per cent. from that obtained by testing the base part of a sound test cup moulded in accordance with test conditions specified in B.S.S. 771 from the same batch of moulding

material. The degree of cure as determined by acetone extraction shall not be more than 6 per cent.

The minimum figures given in B.S.S. 771 are considerably below those usually guaranteed by reputable manufacturers. The following figures are quoted from *A Ready Reference for Plastics*, issued by Boonton Molding Company, U.S.A.:

| Test. | Wood-Flour-Filled Resin. | Fabric-Filled. | Asbestos-Filled. |
|---|---|---|---|
| Tensile strength (lb. per sq. in.) | 6,000–11,000 | 6,500–8,000 | 5,000–10,000 |
| Impact strength (ft.-lb.) | 0·10–0·28 | 0·4–2·4 | 0·11–0·36 |
| Water absorption (24 hrs.) | °0·2–0·6 | 1·0–1·3 | 0·01–0·3 |
| Thermal expansion ($10^{-5}$ per ° C.) | 3·7–7·5 | 2–6 | 2·5–4 |
| Volume resistivity (ohm cm.) | $10^{10}$–$10^{12}$ | $10^{9}$–$10^{11}$ | $10^{9}$–$10^{11}$ |
| Dielectric strength (volts per mil.) | 300–500 | 300–450 | 250–400 |
| Dielectric constant (60 cycles) | 5–12 | | 5–20 |
| Dielectric constant ($10^{3}$ cycles) | 4–8 | 4·5–6 | 4·5–20 |
| Dielectric constant ($10^{6}$ cycles) | 4·5–8 | 4·5–6 | 4·5–20 |
| Power factor (60 cycles) | 0·04–3 | 0·08–0·3 | 0·1–0·3 |
| Power factor ($10^{3}$ cycles) | 0·04–0·15 | 0·08–0·2 | 0·1–0·15 |
| Power factor ($10^{6}$ cycles) | 0·035–0·1 | 0·04–0·1 | 0·005–0·1 |

It is of interest to consider the Post Office requirements for phenol-formaldehyde resins for the micro-telephone set. These are given by E. Marsden, A.M.S.T., F.I.C., "Plastics in Telephone Engineering," *I.P.I. Transactions*, Vol. VII, 1938.

The moulding powder shall be phenol-formaldehyde resin and wood flour.

Total ash, 3 per cent.

Moulded test-pieces are specified and tests given for toughness. Izod impact (1·5 kg. cm. per sq. cm.).

*Plastic Yield.*—Not more than 5 mm. on a cantilever 150 mm. long. 15 mm. cross-section loaded with 450 grm. and yield measured after heating loaded test-pieces for six hours at 140° C.

Cross-breaking strength 15 mm. cross-section, 150 mm. cantilever to withstand proof load of 22½ kilo for 3 min.

*Water Absorption and Dilation.*—A moulded test-piece 50 mm.

diam., 10 mm. thick, with the moulding skin removed and dried for 1 hour at 50° C. to show not more than 120 mgm. of water absorbed after immersion for 7 days. Increase on any dimension not to exceed 0·07 mm.

Resistivity and ultra-violet light test for permanence of dye are also specified.

As mentioned at the commencement of this section, the ordinary grades of phenolic powder do not possess the exceptionally high dielectric strength required for high-frequency radio work, but most well-known manufacturers are able to produce special high resin content powders suitable for the purpose, although even these are not as good as polystyrol. Usually these special powders contain mica as a filler and produce brittle mouldings with somewhat inferior mechanical properties.

The machining of mouldings must be very carefully carried out, especially in the case of mineral-filled resins which are inclined to be more brittle and to fracture easier than ordinary wood-filled resins. In spite, however, of the danger of injury to the moulding, some moulders find it more profitable to carry out a limited amount of machining rather than use a more complicated and therefore more expensive mould. If machining has to be done it is best carried out with very sharp chrome tungsten steel alloy tools. The moulding should, of course, be held in a jig so that absolute accuracy and standardisations of machining is assured. The following notes on machining phenolic mouldings are recommended by the Boonton Molding Company, U.S.A.

1. Do not machine unless absolutely necessary.
2. Diamond cutters are best—then "Stellite" and chrome tungsten steel alloys.
3. Grind your cutter as though you were to cut brass—scrape, do not cut.
4. Get a special drill—they are on the market—having an extra clearance on the edge of the flutes.
5. Use drill speeds of 3,000 r.p.m. on small diameters.
6. For thin sections use a regular twist drill ground to an included angle of 60°, keeping the point at needle sharpness.
7. Do not force the drill, use light pressures.

8. Standardise the number of operations a tool will perform before dulling and change tools at that point. A dull tool will cause rejections.

Where a high degree of accuracy in moulding is advisable, the following precautions in moulding practice are advised by the writers :

1. Dies, preferably 3- or 4-part ones, heated on hot plates at 340–360° F. or same temperature as moulding press before use. Moulding powder, carefully weighed, or pellets may be used, added to the dies on the hot presses, the moulds closed and allowed to remain for a few minutes before pressing.
2. Dies unloaded on hot presses and each moulding placed in a jig and kept under low pressure during cooling.
3. Each moulding carefully examined before dispatching or assembling. In the case of metal inserts it is particularly important to measure the distance between the inserts and to ensure that these have not been deflected from their proper position during moulding.

**Laminated Sheet Material.**

This was originally produced for the electrical industry where there has always existed a growing demand for a structurally strong material that possessed high insulating properties and yet at the same time was non-corrosive in the presence of water, weak acids and weak alkalis and unaffected by immersion in oil. To-day the bulk of the laminated sheet material produced by the plastics industry is still absorbed by the electrical industry. Applications include carbon circuit breakers, linestarters and contactors, oil-immersed control panels and contactor bases, drum controllers, relays, brush rigging, supports for bus bars, coil insulation, transformer coil barriers and numerous applications in radio. It would be impossible to catalogue the hundreds, if not thousands of worthwhile uses of laminated plastics in the electrical field, but sufficient has been said to indicate that these are of the greatest importance. The bulk of applications entail the familiar engineering processes of blanking, piercing and drilling.

Sheets are generally available up to $\frac{1}{2}$ in. thick or more. British Standard Specifications cover two grades of materials; No. 1 possesses a very low water absorption, high resistivity, low dielectric loss and good machining properties and is covered by B.S.S. No. 547, whereas No. 2, which is extensively employed on oil-immersed apparatus and on low voltage apparatus in air in dry situations, is covered by B.S.S. No. 316. The difference between the two grades is accounted for mainly by the difference in resin contents. B.S.S. 547 covers a high resin content material, whereas with B.S.S. 316 the resin content is not so high. The former specification itself deals with two distinct classes of sheet material, or thicknesses $\frac{1}{8}$ in. and below, the first being known as "ordinary" and the thinner sheets below $\frac{1}{8}$ in. for "punching." The latter has a lower resin content than the "ordinary" sheeting.

Three distinct types of bases are used for laminated sheets intended for electrical work: paper; fabric, which may be canvas or linen; and asbestos (chrysotile). The first is recommended for general purpose uses, particularly thin sheets up to about $\frac{1}{32}$ in. for punching; the second where low moisture absorption coupled with high compressive strength and flexural strength are of importance. The asbestos core material is particularly useful where the maximum resistance to heat, coupled with good electrical properties, are specified. Manufacturers frequently produce three of four grades of the paper core material, the first being a standard kraft paper for ordinary use; the second a rag paper of average quality for electrical applications requiring low moisture absorption and the third a special high-grade rag paper base for extremely low moisture absorption and high dielectric strength. The fourth grade, which is really a variation of the first grade, is made specially for punching operations and punches and shears cold up to $\frac{3}{32}$ in.

The most important type of base is paper and for general applications this can fulfil most requirements. It is a good deal easier to machine and work than the fabric or asbestos laminated sheet and does not corrode metal inserts. Fabric-filled sheet material is chemically inert as regards inserts, but asbestos-filled sheet is sometimes rather troublesome owing to the alkaline nature of this mineral. It is, however, quite satisfactory under normal conditions of service.

The machining and punching properties of laminated sheet

depend largely upon the percentage of resin present. High resin content sheet tends to be rather brittle and therefore is liable to split during punching, unless the material is first heated. Brittle sheets, that is, high resin content material, are, however, excellent for drilling, milling and sawing, etc., provided due care is taken and sharp, hard steel tools employed, but where inserts have to be secured by riveting there is a danger of the material crumbling away from the rivets. Briefly it may be said that a laminated sheet with a low moisture absorption machines well but punches badly, whereas a more resilient sheet possessing a higher moisture absorption figure punches very well.

The moisture absorption figure, twenty-four hours, varies from about 0·2 to 3·0 per cent.; this is the average range for high-class material, but the permissible range, according to B.S.S. 547, is a good deal higher. The limit for ordinary material is approximately 0·1 per cent. for $\frac{1}{2}$-in. sheet to 1·6 per cent. for extremely thin sheet only $\frac{1}{64}$ in. in thickness, but the range for the punching grade is approximately 1 per cent. for $\frac{1}{8}$-in. sheet to 4·5 per cent. for $\frac{1}{64}$-in. material. Manufacturers realise the great importance of water absorption and quite frequently publish data showing loss on drying one hour at 100° to 105° C. gain in weight after two hours' immersion in water; gain in weight after twenty-four hours' immersion in water and gain in weight at saturation. The figures for one of the longest ranges of laminated sheet (Micarta) are given below:

| Micarta Grade No. | 200 | 213 | 219 | 221 | 222 | 223 | 238 | 254 | 262 |
|---|---|---|---|---|---|---|---|---|---|
| | — | 423 | 429 | 431 | 432 | 433 | 448 | 464 | — |

MOISTURE ABSORPTION

| Test-piece 3 × 1 × $\frac{1}{16}$ in. | Per cent. | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Loss on drying one hour at 100°–105° C. . . | — | 0·5 | 0·3 | 0·3 | 0·6 | 0·3 | 1·0 | 0·3 | — |
| Gain in weight, two hours' immersion in water . | — | 1·3 | 0·3 | 0·2 | 0·7 | — | 1·2 | 0·2 | — |
| Gain in weight, twenty-four hours' immersion in water . . . . | 1·1 | 4·7 | 1·2 | 0·6 | 2·5 | — | 3·0 | 1·0 | — |
| Gain in weight at saturation . . . . . | — | 14·5 | 6·0 | 4·5 | 8·0 | 4·0 | 6·0 | 6·0 | 7·0 |

In the B.S.S. test a specimen 1½ in. square, which has four smooth edges freshly cut immediately before the test, shall be weighed after it has been conditioned by exposure to a controlled atmosphere, relative humidity 75 per cent. at a temperature between 15 and 25° C. for not less than eighteen hours. The specimen shall then be immersed in distilled water at a temperature of 20° C. (± 2° C.). After twenty-four hours' immersion it shall be taken out of the water and after removal of surface moisture by wiping, be weighed again.

It will be noticed in the data given for Micarta, which is manufactured by Westinghouse Electric, U.S.A., that information is afforded regarding the water content of the laminated sheet. This is most important as not only will the presence of moisture within the material interfere with its electrical properties, but also accelerate the absorption of moisture. This can be seen from the above figures, the grade showing the highest loss on drying is also the one showing the highest gain after immersion. There is no mention of the natural water content of laminated sheeting in B.S.S. 547 or 316, although, obviously, a test for this should be included in the specifications.

The most important electrical tests applied to laminated sheets are: insulation resistance, electric strength at 90° C., surface breakdown in air, after immersion in water and breakdown along laminæ in oil. B.S.S. 547 lays down the following limits: The insulation resistance as tested under conditions described in Appendix C, B.S.S. 547, should be not less than 1,000 megohms. As regards electric strength of sheets as tested according to the recognised B.S.S. test every sheet shall withstand for one minute without failure the following voltages. The ½-in. sheet must have a figure of 40 kilovolts; ¼ in. approximately 33; ⅛ in. about 25; $\frac{1}{16}$ in. approximately 18.

The figures given in B.S.S. 547 for surface breakdown in air, after immersion in water, as tested according to the conditions laid down in Appendix E, are as follows: Sheet up to and including $\frac{1}{32}$ in. must withstand for a minimum period of one minute without breakdown 10 kilovolts; above $\frac{1}{32}$ up to and including ½ in. 14 kilovolts. The breakdown along laminæ in oil is a very important test. Every sheet, when tested, shall withstand for one minute without failure a test voltage of 25 kilovolts.

Generally speaking, the minimum figures laid down in B.S.S.

547 are on the low side, and most of the well-known materials possess electrical properties superior to those specified.

The following figures are representative of good grade laminated materials, paper base, fabric base and asbestos cloth base. The figures are quoted from the October 1939 number of *Modern Plastics*.

ELECTRICAL PROPERTIES OF LAMINATED SHEET

| Properties. | Paper Base. | Fabric Base. | Asbestos Cloth Base. |
|---|---|---|---|
| Volume resistivity (ohm.–cm.) (50% relative humidity and 25° C.) | $10^{10}$–$10^{13}$ | $10^{10}$–$10^{12}$ | — |
| Breakdown voltage (60 cycles, volts per mil) (instantaneous) | 400–1,300 | 150–600 | 60–150 |
| Dielectric Constant, $10^6$ cycles | 3·6–5·5 | 4·5–7 | — |
| Power Factor, $10^6$ cycles | 0·02–0·05 | 0·02–0·08 | — |
| Water Absorption, 24 hours | 0·3–9·0 | 0·3–9·0 | 0·3–2·0 |

**Impregnated Tubes and Cylinders.**

These are made from paper or other suitable base impregnated with an alcoholic solution of phenol-formaldehyde resin and wound on a mandrel of the required diameter. These are later oven cured or moulded under heat and pressure. Tubes are finished to exact size by grinding. There is a great demand for these in the electrical industry where they are used for the manufacture of high-voltage bushings, etc. Usually three different bases or fillers are used: paper, fabric and asbestos cloth. The electrical and physical properties of these tubes depend on four outstanding factors:

1. The type of resin employed.
2. Percentage of resin present.
3. Time of cure.
4. Type of base.

B.S.S. 316 refers to two grades of what is known as "varnish-paper boards (or tubes)" but only covers Grade 2.

Grade 1 material includes synthetic resin varnish-paper boards and tubes, the principal characteristics of which are relatively low water absorption, high resistivity, low dielectric loss at radio frequencies, and good machining properties. This grade is generally

employed on apparatus when it is important that high insulation resistance shall be maintained under all conditions of humidity, and for use at radio frequencies. Grade 2 includes synthetic resin varnish-paper boards and tubes, the principal characteristics of which is high electric strength at high temperature. This type is generally employed on oil-immersed plant where high electric strength is required at high temperature, and on low-voltage apparatus in air. In general this grade has not as good machining properties at Grade 1, but is less brittle.

The following tolerances on internal diameter and external diameter of tubes are given in B.S.S. 316.

Up to and including $1\frac{1}{2}$ in. internal diameter the maximum permissible tolerance on internal diameter plus or minus is 3 mils, and 5 mils for tubes above $1\frac{1}{2}$ up to and including 3 in.

As regards external diameters of tube, the tolerance on the external diameter shall not exceed plus or minus 10 mils (0·254 mm.) on tubes up to 4 ft. in length and pro rata for tubes of length greater than 4 ft. Tolerance on wall thickness of tubes is given :

| Limits of Nominal Wall Thickness of Tubes. | Maximum Permissible Tolerance on Wall Thickness. |
|---|---|
| Up to [illegible] | — 5 per cent. |
| Above [illegible] in. and up to $\frac{1}{8}$ in. | — 3 ,, ,, |
| Above [illegible] in. and up to $\frac{1}{4}$ in. | |

The following is a summary of the minimum electrical properties allowed by B.S.S. 316 :

Insulation resistance of any tube of any internal diameter up to 4 in. and of any thickness of wall up to $\frac{1}{4}$ in. shall not be less than 1,000 megohms when tested according to tests described in Appendix IV.

Electric strength at 90° C. of every tube up to 3 in. internal diameter when tested by method described in Appendix V, shall withstand the following :

| Limits of Nominal Wall Thickness of Tube. | Minimum Volts per mil. | Minimum Volts per mm. |
|---|---|---|
| Up to and including $\frac{1}{8}$ in. . . | 250 | 10,000 |
| Above $\frac{1}{8}$ in., up to and including $\frac{1}{4}$ in. | 200 | 8,000 |

Surface breakdown in air for tubes up to 3 in. internal diameter when tested by standard method shall withstand 12 kilovolts for one minute.

Breakdown along laminæ under oil shall be tested by application of a test voltage of 20 kilovolts for one minute along the laminæ without signs of breakdown.

**Resin-impregnated Wood.**

This is now being extensively employed in the manufacture of switches of high-rupturing capacity, bus bar supports, stators, transformer rings, outlet terminal boards, assembly rods, core spacers, transmission line cross arms, fishguards for electric rail tracks, etc. The New Insulation Co. Ltd., of Gloucester, manufacturers of the well-known French resin-impregnated wood, Permali, state that in switchgear construction their material finds a place primarily as a material for high tensile operating links and rods. It is also being very successfully employed as a material for various arc extinguishing devices, for the operating parts of isolating and auxiliary switches, for the spreaders in cable-dividing boxes, and as a general insulating medium for the support or operation of contacts. In transformer construction it is now being widely used in the form of rings as " end insulation " on windings, etc.

Grades of resin-impregnated wood are available possessing varying mechanical and electrical properties according to the thickness of the veneers employed, the direction of the grain of the wood and also the degree of resin impregnation. Manufacturers specialising in the production of resin-impregnated wood usually turn out the finished electrical components instead of just disposing of the material in the form of planks, tubes, rods, etc., to firms for fabrication.

The electrical properties of Permali are given by the manufacturers as follows :

The electrical properties of the material remain stable and undergo no change with the age of the material.

*Specific resistance.*

| | |
|---|---|
| Measured on samples 1 cm.$^2$ × 1 in. long | $2 \times 10^{10}$ ohms |
| After immersion in cold water (62° F.) for 36 hours and surface dried . . . | $48 \times 10^6$ ohms |
| After immersion in water at 212° F. for 3 minutes, cooled and surface dried . | $3{\cdot}8 \times 10^6$ ohms |

*Dielectric loss at 50 cycles* (measured in milliwatts per cm.$^3$ at 1 kV per cm.).

0·10. Unchanged when measured on 10 successive days.

Results on equal specimens of linseed oil impregnated wood gave:

| | | |
|---|---|---|
| After 2 days | . . . . . | 1·4 milliwatts |
| ,, 4 ,, | . . . . . | 14 ,, |
| ,, 10 ,, | . . . . . | 39 ,, |

Dielectric loss at radio-frequency compared in materials:

Quartz: 0. Permali 6.

Paper: 10. Rubber 8.

*Dielectric constants.*

At 50 cycles. Not exceeding 5.

Loss angle less than 0·05.

*Moisture absorption.*

2·5 per cent. increase in weight in twenty-four hours.

Specimens dried in oven at 101° C. for fifteen days and reweighed after immersion in water at 25–35° C. for twenty-four hours. The water absorption after twenty-four hours' immersion without previous drying is about 1·2 per cent.

## Urea-Formaldehyde Resins.

These find very similar applications to the phenolic resins, but are generally only produced in paper- and wood-filled varieties. Owing to the fact that urea resins are available in white and a wide range of delicate pastel tints, their field of application in the domestic world has been greatly increased. Although it is claimed that the colours are permanent, that is, non-affected by exposure to light, this is not always borne out in practice. Dr. W. Blakey (*Electrical Review*, Jan. 21, 1938) mentions that urea resins are suitable for use up to about 100° C. and that they are used for components, such as switch-bases, formerly made of porcelain, also for complete switches, plugs, sockets, adaptors, meter cases, magneto and coil parts, switch plates, light fittings (including shades), junction boxes, ceiling roses and radio parts.

Generally speaking the electrical properties of the paper-filled urea and the ordinary type of wood-filled phenolic resins are similar, with the exception of "tracking" properties. The urea resin is characterised by freedom from tracking and this enables it to be used for purposes where the ordinary phenolic resin would

prove unsuitable. An outstanding difference between the two resins is the much higher moisture absorption figure of urea as compared with phenol formaldehyde, the former being round about 1–2 per cent. and wood-filled phenolic approximately 0·2–0·6 per cent. in twenty-four hours. Immersion in water for twenty-one days showed a moisture-absorption figure for urea resin of 5 per cent. and dimensional increase from 1·0 to 3·0 per cent. The high moisture absorption of urea resin renders it unsuitable for continual use under damp conditions and would appear to render doubtful, if not entirely negative, its "non-tracking" property under such conditions.

Urea resins are not as stable as ordinary phenolic resins at elevated temperatures and E. E. Halls, *Plastics*, July, 1938, has stated that at a temperature of 70° C. in twenty-one days the average weight loss is of the order of 5·2 per cent. and the dimensional decrease 1·5 to 3·0 per cent., according to the section concerned.

In view of the colourful effects obtainable in urea-formaldehyde resin the most obvious uses of this plastic are in the domestic field where service conditions are known to be reasonably good. As stated previously, the resin possesses good electrical properties and is also very robust and well able to stand up to normal usage without fear of breakdown. Its weaknesses are only shown under abnormal conditions of use, although it has to be admitted that a small amount of shrinkage does take place, even on storing mouldings under perfectly dry conditions. Except for very fine work, however, the degree of shrinkage in the dry may not interfere with the normal working of the component, but where a high degree of dimension stability is essential then even a slight variation may render the moulding quite unsuitable.

**Aniline-Formaldehyde Resin.**

Where resistance to heat, high electric strength and non-liability to tracking are required then aniline-formaldehyde resin offers great advantages over the phenol-formaldehyde resins. One of the best-known aniline resins used in the British electrical industry is manufactured in Great Britain by the Micanite and Insulators Co. Ltd., under their own trade name, "Panilax," which is produced in the form of a bonded paper and also as a pure resin moulding. The former is made by incorporating the

resin in the fibre or paper pulp during the actual process of making the paper, so that the whole texture of the finished product is permeated. A board for general purposes has a resin content of 45 to 50 per cent. of resin.

The electrical properties of "Panilax" and a similar board impregnated with phenolic resin are given by Micanite & Insulators Co. Ltd.

| | "Panilax." | Phenolic. |
|---|---|---|
| Density | 1·32 to 1·36 | 1·30 to 1·35 |
| Water absorption on ¼ in. thickness: | | |
| 24 hours | 0·22% | 0·5% |
| 7 days | 0·9% to 1·0% | 2·5% |
| Minute breakdown value through laminæ in oil at 90° C. ¼ in. thick Volts per mil. | 350 | 250 |
| Minute breakdown value along laminæ in oil at 90° C. in V per inch | Above 70,000 | 35,000 |
| Power factor, ¼ in. thick at 20° C. | 2% to 6% | 10% |
| Tensile strength (lb. per sq. in.) Min. | 14,000 | 10,000 |
| Shearing strength (lb. per sq. in.) Min. | 12,000 | 11,000 |
| Cross breaking strength (lb. per sq. in.) Min. | 25,000 | 19,000 |
| Compression strength (lb. per sq. in.) Min. | 35,000 | 25,000 |

The electrical properties of pure "Panilax" without filler are as follows:

| | | |
|---|---|---|
| Density | 1·2 to 1·25. | |
| Tensile strength | 8,500 to 10,000 lb. per sq. in. | |
| Transverse strength | 14,000 to 17,000 lb. per sq. in. | |
| Impact | 6 to 9 ft.-lb. per sq. in. | |
| Young's modulus | 280,000 to 420,000 lb. per sq. in. | |
| Plastic yield (VDE Martens) | Higher than 95° C. | |
| Permittivity | 3 to 4. | |
| Minute breakdown value in oil at 90° C. for ¼ in. to ⅜ in. thickness | 250 volts per mil. | |
| Water absorption at 20° C.: | | |
| 24 hours | 0·05% | |
| 7 days | 0·14% | |
| Power factor: | *at 25° C.* | *at 90° C.* |
| tan *d* at 50 cycles | 1·0 % to 2·0% | 2% to 12% |
| tan *d* at radio frequency | 0·15% to 0·3% | 0·2% to 1·0% |

**Polystyrol.**

Owing to its extremely low loss factor at high frequencies, high dielectric strength and very low moisture-absorption figure, this comparatively new commercial resin is now finding many important applications in the radio field. The electrical properties of polystyrol are as follows:

| *Frequencies* | *S.I.C.* | *Loss Factor.* |
|---|---|---|
| 50 | 2·2 | 0·0002 |
| 1000 | 2·2 | 0·0005 |
| 200000 | 2·1 | 0·00044 |
| 650000 | 2·1 | 0·0002 |
| 1000000 | 2·3 | 0·0002 |
| 40000000 | 2·3 | 0·0001 |
| Breakdown voltage (50 cycles, volts per mil.) | | 500–700 |
| Volume resistivity | | $> 10^{17}$ |
| Surface resistivity | | $> 10^{16}$ |

(The above tests have been carried out on Distrene, which, it will be seen, is an exceptionally good material.)

Polystyrol is usually available in the form of a white powder, S.G. 1·05, suitable for either injection or compression moulding. It may, if desired, be used with an asbestos filler, but most manufacturers prefer to produce a glass clear moulding and dispense with the extra strength afforded by the mineral fibre. Extruded rods and blocks are, however, also available and these may be machined, provided the tool temperature is kept below 70 to 95° C. Moulded parts may also be machined and such machining is not generally so hazardous as in the case of thermo-setting mouldings. Mouldings can, of course, be produced with metal inserts and their mass production is quite economic.

As mentioned at the commencement of this chapter, polystyrol is by no means a strong material, its chief weakness being its low impact strength, which is only 0·25–0·5 ft.-lb. compared with 1·0 for moulded acetate. The thermal expansion of polystyrol is also rather high, although only half that of acetate, and, of course, considerably greater than the thermo-setting materials.

The ageing properties of this resin vary a good deal and whilst some users report cracking and crazing, others have no complaints. A great deal, of course, depends upon the type of plasticiser used and the conditions of moulding the powder.

**Cellulose Acetate.**

This plastic possesses moderately good electrical properties and has the advantage of being highly resistant to shock and therefore very suitable for those applications necessitating the use of a high impact strength material. Its water-absorption figure is, however, rather high, approximately 1·4–2·8 in twenty-four hours, and its softening and therefore distortion figure is approximately 122–212° F. Ageing properties of this ester are not as good as those of the thermo-setting resins and although its tendency to cold flow is only slight, it is considerably higher than the stable and inert phenolic resins.

The most useful applications of cellulose acetate in the electrical field are switch dollies, lampshades, instrument dial faces, radio dials, windows, choke coverings, formers, trafficators, etc.

Acetate is available in several different forms : fine powder for injection and compression moulding ; extruded rods and tubes and sheets of various sizes and thickness in transparent, translucent and opaque colours. The sheets are usually available in the following surface for lampshade manufacture :—knife lines, matt ; rough matt ; polish ; permanent polish and tissue paper. All grades are obtainable in glass clear transparent form, as well as an extensive range of colours. Machining of this plastic offers no difficulties.

**Later Cellulose Plastics.**

Some attention has recently been given to the later additions to the cellulose plastics, particularly the mixed esters, such as cellulose acetate butyrate, also benzyl cellulose and ethyl cellulose. In many ways the acetate butyrate is an improvement on the straight acetate, particularly as regards moisture absorption, this being 0·8–1·1 per cent. in twenty-four hours. The power factor of acetate butyrate is also much lower than the acetate ; for $10^6$ cycles the figure is approximately 0·018 compared with 0·04–0·06. As regards physical tests, the impact strength of the mixed ester is definitely superior to the acetate, the figures being 1·3–3·3 ft.-lb. (Charpy) compared with 0·9–1·6 ; tensile strength and compressive strength of acetate butyrate are lower than acetate, but elongation slightly better.

Hercules Powder Company, who manufacture both benzyl

ethyl cellulose and cellulose acetate, give the following electrical properties for these compounds :

| | Dielectric Constant (1,000 cycles). | Power Factor (1,000 cycles) (%) | Dielectric Strength (Volts per mil.). | Specific Surface Resistivity (ohms × $10^{-10}$). |
|---|---|---|---|---|
| Ethyl cellulose | 3·9 | 0·25 | 1,530 | 2,000 |
| Benzyl cellulose | 3·4 | 0·24 | 2,200 | > 10,000 |
| Cellulose acetate | | | 1,400 | 15 |

The following table shows the effect upon the power factor of immersion of the films in water (films were between 5 and 10 mil. thick) :

| | Power Factor. | Immersion in $H_2O$ (Hours). | |
|---|---|---|---|
| | 0. | 20. | 40. |
| Ethyl cellulose . . . . | 0·17 | 0·20 | 1·90 |
| Benzyl cellulose . . . | 0·20 | 0·21 | 0·42 |
| Cellulose acetate . . . | 0·50 | 0·50 | 3·92 |

Ethyl cellulose, which is highly flexible, resistant to ultra-violet light and stable up to 125° C., is being used as a cable-sheathing and wire-coating material.

**Acrylic Resins.**

Methyl methacrylate resin, as typified by " Perspex " and " Diakon " (British), " Plexiglas " (German) and " Lucite " (American), possesses reasonably good electrical properties and a low moisture-absorption figure (0·4–0·5 in twenty-four hours). Acrylic resin is available in two forms, powder for injection or compression moulding, cast rods, tubes and also sheets. The resin may be machined almost as easy as acetate. Impact strength is not as high as acetate, 0·25–0·5 ft.-lb. (Charpy) against about 1·0 for moulded acetate. Its burning rate is slow, similar to acetate. Ageing properties are, however, superior to those of the cellulose ester. The principal disadvantage of acrylic resin is its high price, which, unfortunately, rules out some electrical applications. In spite of this, many British G.P.O. telephone

receivers are now being moulded of Diakon because of its excellent properties.

**Vinyl Resin.**

This resin finds its principal applications in the form of extruded tube for cable sheathing. The best-known vinyl polymers are Koroseal, Mipolam, Oppanol, Astralon, etc., all of which are non-hygroscopic, resistant to ozone and possess excellent insulating properties as well as a high resistance to the corrosive effects of oils, solvents and chemicals ; their ageing properties are also extremely good. Breakdown voltage of Mipolam is within the range of 30,000 to 40,000 volts per mm. wall thickness. In the case of Mipolam, two grades are available, one for insulation possessing very high electrical properties and the other for the outer-covering or substitute for metal braid, etc. These resins are available in a number of different colours and in different degrees of hardness according to the degree of plasticity.

The following electrical properties of Mipolam are given by the manufacturers :

| | | |
|---|---|---|
| Dielectric resistance *kv/mm* | | |
| Creeping current resistance | | Firm |
| | *For Insulation.* | *For Sheathing* |
| Internal resistance M.O. direct. | > 3 million | 70,000 |
| Surface . . . . . | 1 million | 13,000 |
| Dielectric constant (800 Hertz) direct . . . . | 4·2 | 7·9 |

## CHAPTER VII

# AIRCRAFT CONSTRUCTION

ROBBED of all sensationalism, the rôle of plastics in aircraft construction is a most important one and there is every reason to believe that its importance will increase as the result of direct encouragement by the British Air Ministry, who are at the present time urging aircraft manufacturers to exploit the possibilities of plastics for many unstressed and lightly stressed parts now made of light alloys. In the Circular Letter No. 127, October 12, 1939, the Director of Aircraft Contracts gives a list of available alternative materials :

1. Steel.
2. Reinforced synthetic resins—sheet, tubing and moulding.
3. Compressed laminated wood.
4. Pigmented cellulose acetate sheets (D.T.D. 315).
5. Laminated paper.

Recent research indicates that even for certain stressed parts plastics offer distinct promise when designed by the aircraft designer and plastic fabricator working in close collaboration ; or better still, although very rare, the fabricator who has himself the necessary knowledge and experience of aircraft construction. It must, however, be admitted that there is a dearth of information on the stress-strain relationship and flow at temperatures liable to be experienced in service. These may vary very considerably from $-40°$ F. to $+145°$ F. and it is essential that even these limits should not be taken as being minimum and maximum.

It is an encouraging fact that some enlightened plastic fabricators are seeking the assistance of the Air Ministry Laboratory at Farnborough and also working in co-operation with the Research Laboratories of the large aircraft manufacturers. Only in this way

can real progress be made, especially as regards the development of stressed parts where data on fatigue is of the greatest importance.

So far thermo-plastic materials are used to a greater extent than the thermo-setting resins, because in the main they are more adaptable to series production than the latter, which are primarily intended for mass production.

This factor is important in view of the many modifications of design which take place before a new craft is ready for its trials. It is claimed with some degree of authority that more than 2,000 changes are made by designers and engineers after the plans have been drawn up, and although many of these are slight, others necessitate drastic alterations. Whilst it is a comparatively simple matter to alter the shape of a moulded or formed acetate production by slight adjustments to the simple wooden jig, or by merely sticking patches on to sections requiring strengthening, etc., it is a very difficult and expensive matter, even if it is possible, and this is not always so, to make structural changes in the shape of the steel mould required for phenolic resins. The reason can therefore be appreciated that thermo-plastics are fundamentally ideal materials for the aircraft designer, although he must appreciate the fact that the ideal plastic does not exist. Such materials as cellulose acetate and acrylic resin have limitations, the most important being their relatively low softening properties which render them somewhat hazardous for use under exceptionally severe tropical conditions. It should, however, be stressed that these conditions must be severe and that under normal flying conditions the thermo-plastics give every satisfaction. On the other hand, the thermo-setting resins, although not possessing the adaptability and easy and economical working properties of acetate, possess superior mechanical strength and are completely unaffected by temperatures exceeding 122° F., the temperature at which acetate is liable to become distorted.

It is a somewhat lamentable fact that aircraft designers and draughtsmen have a very meagre knowledge of plastics. To most of them the thermo-setting resins are typified by ordinary wood-filled phenol-formaldehyde resin mouldings. Yet the range is extensive and the materials even in one class very varied in their characteristics. Take, for instance, the phenolic moulding resin. Mechanical properties may range from 4,000 to 11,000 lb. per sq. in. tensile strength with a wood filler ; 4,000 to 10,000 with a

mineral filler; 6,500 to 8,000 with a macerated fabric filler. Impact strength figures for the same type of resins vary even more widely, the fabric-filled powder being ten times as strong as the best wood-filled grade. Lack of knowledge of the plastics now available for commercial use often leads designers to specify one kind of material when another type would serve the purpose far better. An instance of this was given to the writers a short time ago by a fabricator specialising in aircraft work. He said that he was given a trial order for an instrument tray to be made in transparent acetate sheet. When he pointed out that if the same tray were made in black acetate sheet the cost would be reduced by nearly 30 per cent. for material alone, his clients were surprised because they were totally unaware that black acetate sheet was available.

Those with small experience of the advantages of plastics in aircraft construction immediately confront one with a comparison of costs of aluminium alloys and plastics. In the case of acetate sheet, the most commonly used plastic, this ranges in price from 3*s*. 6*d*. per lb. for the black to 5*s*. per lb. transparent, whereas Duralumin is only 2*s*. 6*d*. per lb. On this basis the alloy would appear to be much more economical, but there are several factors to be taken into consideration. Probably the most important is the wastage which occurs in working all metal. It has been calculated that in the fabrication of Duralumin parts at least 80 per cent. is wasted, but even if this figure is reduced to 50 per cent., the price immediately jumps to 5*s*. per lb., the price asked for transparent grade acetate. Then, again, there is a very considerable difference in the cost of working acetate and Duralumin, so that it is possible to turn out the former a good deal cheaper and quicker than metal parts. In war-time the time factor is of great importance and this is where the acetate mouldings score, as it is practical to produce them in one-tenth the time required for turning out similar ones in alloy. Ease and speed of manipulation, vital in a national emergency, cannot be claimed for phenolic mouldings, as first of all dies have to be made, which are not only very expensive, but may take several weeks to make, even when the metal is readily available. Of course, once the tools are fixed up in the press, then production is exceedingly rapid. Here again, however, the ability to produce large quantities of standardised mouldings is not a great advantage in aircraft manufacture because of the fluid nature of

designs, which frequently necessitate large numbers of modifications.

**Cellulose Acetate Productions.**

Very extensive use is now being made of acetate for aircraft components. This may well be judged when it is stated that for one type of military plane twenty applications are found for acetate parts. These include tail wheel fairing ; intake for cockpit heating to radiator ; radio mast fairing ; de-icing for radio aerial ; main plane root fillet ; tail plane and fin root fillet ; oil cooler leading edge air inlet ; transparent windows ; camera window draught shield, etc.

As mentioned previously, acetate sheet material is available in two standard grades, transparent and black. There is also a wide range of colours, both transparent and opaque, for certain applications. Extruded tubes are being used to a growing extent for conduits and ducts and powdered acetate is employed for the injection and compression moulding of various small parts, such as lamp shields or covers. The main applications are, however, confined to the sheet, which is available up to $\frac{3}{4}$ in., although it is rare, indeed, that thicknesses in excess of 6 mm. are required for formed pieces.

Earlier in this chapter the ease with which it is possible to work acetate sheet by shaping was stressed. It was not mentioned, however, that one of its most important properties is its deep drawing qualities, so that wing-tips measuring 11 in. deep and 4 ft. long can be made in one operation, whereas, of course, it would need several to produce the same tip in aluminium.

Owing to the reluctance of plastic manufacturers to supply extruded acetate tubes in various diameters, very little use has been made of these for conduits, although they are well fitted for this purpose. It is, however, encouraging to note that a rather belated, but nevertheless welcome attempt is being made to make up the leeway and tubes are becoming available for the fabricator, who hitherto has been forced to make his own.

During the last two years the size of acetate mouldings has increased many times and no one dare predict what the future has in store. The largest piece the authors have seen is a nacelle fairing measuring, roughly, over 5 ft. in length. The most complicated is certainly the dinghy box used for holding the com-

pressed air bottle and collapsible rubber dinghy, which all aircraft crossing the sea now carry as part of their standard equipment.

Sheets of acetate material are usually cut with a band or circular saw, preferably the former, as it gives a cleaner cut. This method of cutting is recommended instead of using scissors and cutting to shape when the sheet has been softened in the air oven.

Machining, such as drilling, milling, turning, routing, can be undertaken with standard equipment and the material responds well to the ordinary treatment meted out to wood and soft metals.

As regards injection and compression moulding, methods of carrying out these highly important processes are referred to elsewhere, but for the convenience of the aircraft manufacturer who may just look up this chapter and neglect the remainder of the book, it can be said that compression moulding requires an average temperature of approximately 250–350° F. and a pressure varying from 1,500 to 5,000 lb. per sq. in.; injection moulding temperature is higher at 300–440 and pressure 8,000 to 30,000 lb. per sq. in. Prices of presses vary considerably, but in 1939 a good injection moulding machine was priced in the region of a thousand pounds.

One of the most interesting uses of acetate sheet material is for covering the Schwarz airscrew. The acetate in this case is reinforced by linen fabric, the whole measuring approximately 0·040 in. thick. This protective cover is applied to the wooden blade when properly softened by heat and maintained under pressure until it has annealed perfectly to the base. Afterwards the surface is well sanded and finally coated with a special enamel. The Schwarz Company guarantee their screw for 1,000 hours' service within two years, with the stipulation that the coating must be repaired immediately it is worn through. Important advantages which are claimed for this protective coating are that the pores of the wood are effectively sealed, ice formation reduced to a minimum, indeed it has not so far been reported on the screw although present on the hub, and the ability of the covering to indicate dangerous stresses by cracking or splitting in a certain well-defined manner.

### Acrylic Resin Sheet.

The English material Perspex is used for hoods, gun-turrets and other parts of the machine requiring a highly transparent

material. The method of working is in many ways similar to that explained for acetate sheeting, except that greater care has to be taken in handling and the sheet of white paper used as a protection for every sheet of Perspex should be retained in position. This can later be removed and the gelatine adhesive washed away with a little soap and water.

The sheet is cut to the required size with a high-speed band or circular saw. It is then hung up in a hot-air oven at a temperature ranging from 100 to 120° C. I.C.I. recommend the following heating conditions :

| *Thickness of Sheet* (in.). | *Temperature of Air Oven* (° C.). | *Time of Heating* (minutes) |
|---|---|---|
| $\frac{3}{32}$ to $\frac{1}{4}$ . . . . . . | 100–105 | 10–15 |
| $\frac{5}{16}$ to $\frac{3}{8}$ . . . . . . | 115–120 | 20–30 |

Dealing with formers or moulds, the advice given by I.C.I. Ltd. to manufacturers contemplating use of their own material, Perspex, is as follows :

> Types which may be employed are largely dependent on the shaping it is desired to carry out. They may consist of male and female portions suitably located relative to each other and between which the "Perspex" is formed to the shape required. On the other hand, they may consist of a male portion only, in which case, if a simple single curvature is required, it may suffice merely to lay the heated material over the former and retain it in place while it is cooled. If double curvature is required, it may be necessary to stretch the material over the former by means of rings or other suitable devices whereby tension may be exerted on the edges of the material.

Shallow mouldings can be made at a temperature of about 95° C. and it is stated that good pressings may be made on well-sanded wooden formers without a surface covering, such as rubber, although the latter is recommended for the best results. "Perspex" shaped by this method should be annealed for several hours at 55–60° C.

Acrylic resin sheet can be formed by blowing and may be worked almost as easily as acetate sheets using standard equipment and tools. Cementing is not as easy as in the case of acetate, but strap joints can, it is claimed, be as strong as the sheet, butt joints being somewhat weaker. The finished work can be polished by

rubbing first with No. 1 emery paper and then with a series of finer grades. Subsequent rubbing with a soft cloth or mop gives a brilliant surface. Small scratches can easily be removed by vigorous polishing with a good metal polish and subsequent light polishing with a metal polish thinned down with paraffin.

### Impregnated Wood.

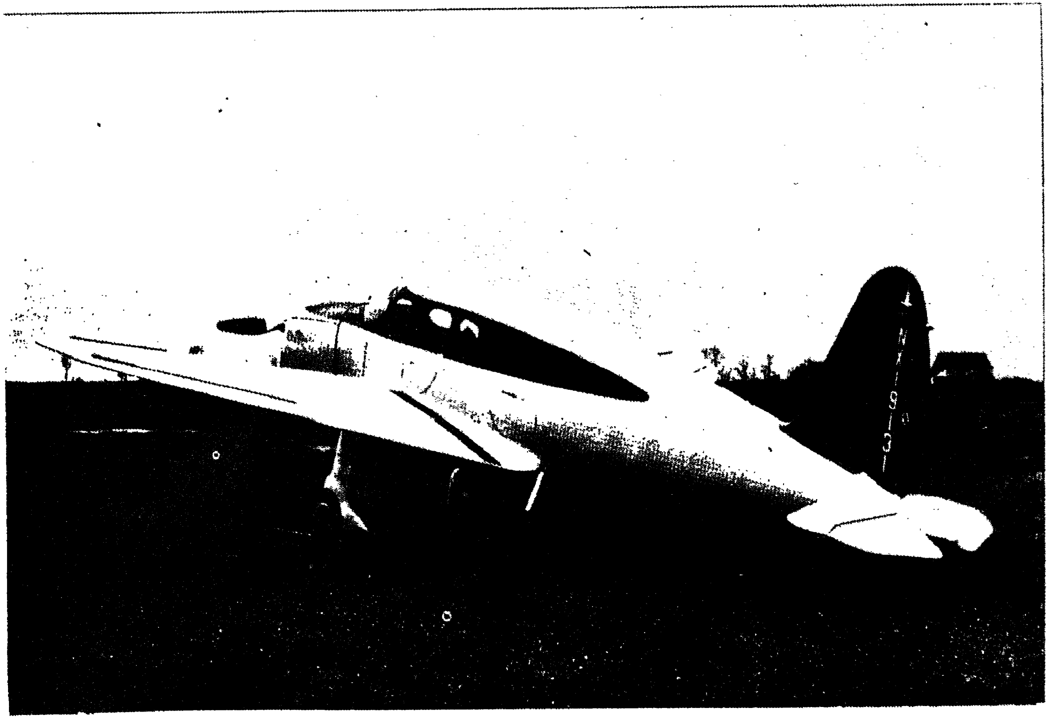
A good deal of interest is now being taken in the use of compound woods made up of very thin veneers, usually about 0·1 to 0·3 mm. thick, impregnated with an alcoholic solution of phenolic resin and pressed together under heat and heavy pressure so as to form a very strong and rigid material with a specific gravity of approximately 1·27–1·4. Compressed wood is also made by subjecting veneers with interlayers of synthetic resin adhesive, either in the form of liquid or solid coatings, to heat and pressure. The difference between the impregnated and the compressed wood is that the former is somewhat lighter in weight and possesses a higher impact strength. On the other hand, the impregnated wood has a higher Brinell hardness, superior tensile strength and improved electrical properties. Both types of wood find important applications in aircraft construction.

The most publicised type of impregnated wood is Duramold, a product evolved by the joint efforts of the Haskelite Corporation and the Bakelite Corporation, U.S.A., and used for the fuselage of the now famous "Clark 46," the first experimental aeroplane to be made largely of plastics. Colonel V. E. Clark (*Aero Digest*, 1939) states:

> calculations based on wind tunnel tests at fairly high Reynolds Number indicate that for a high-speed aeroplane having Duramold fuselage, wings and fixed tail units, about 25 per cent. less power will be required at given high speed than an all-metal plane with projecting rivet heads, lap joints and the waves and wrinkles which are present in flight or after service in an all-metal plane.

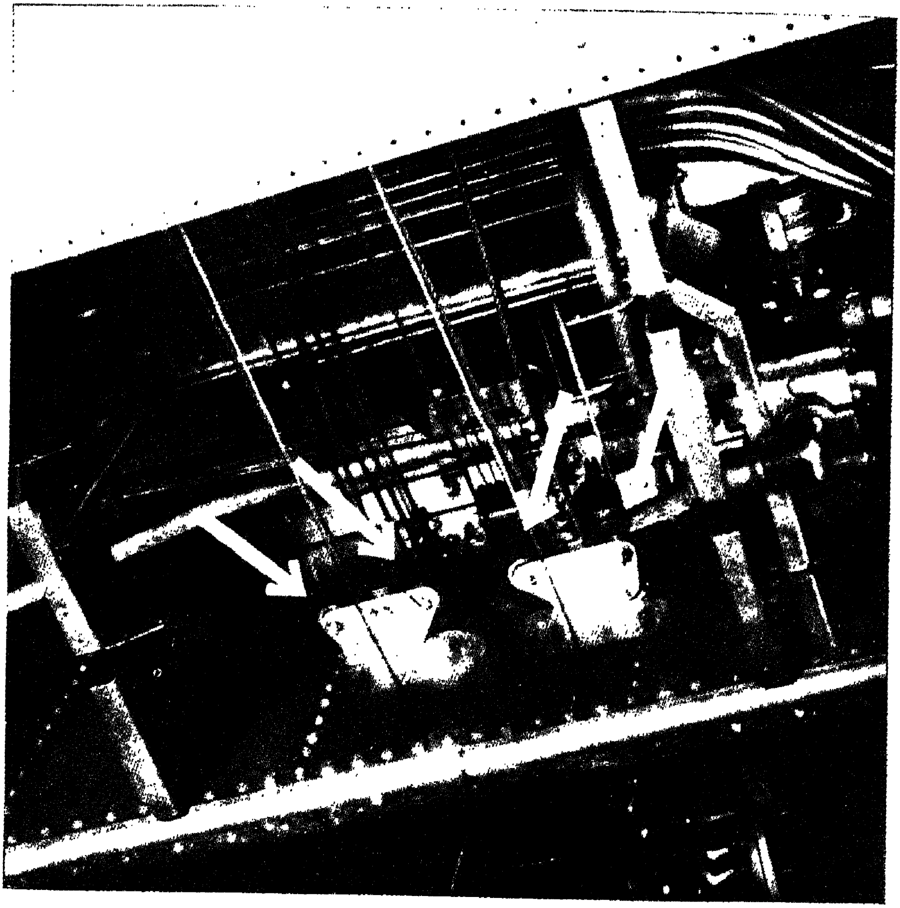
The data in the table opposite is given by Colonel Clark regarding the properties of the new material.

It will be seen that various grades of Duramold are available and, although no information is available, the authors imagine that the various types correspond to changes made in the position of the laminæ. This is, of course, the usual practice by manu-



Aircraft fuselage moulded in two sections from "Duramold" (hardwood veneer impregnated and bonded with Bakelite phenolic resin).

[Facing p. 100.



Aircraft pulleys (indicated by arrows) made of laminated material by Westinghouse Electric & Manufacturing Co.

*Facing p.* 101.]

Approximate values in lb. per sq. in. divided by (1,000 × sp. gravity)

| Type of Duramold. | Direction of Applied Load. | Tension. | Compression. | Young's Modulus T. and C. |
|---|---|---|---|---|
| I | Optimum . . . | 25·75 | 13·95 | 3,060 |
| I | 90° to opt. . . . | 4·72 | 7·70 | 714 |
| II | Optimum . . . | 22·73 | 13·03 | 2,730 |
| II | 90° to opt. . . . | 7·75 | 8·60 | 1,053 |
| III | Optimum . . . | 19·69 | 12·08 | 2,380 |
| III | 90° to opt. . . . | 10·80 | 9·51 | 1,395 |
| IV | Optimum . . . | 16·75 | 11·22 | 2,040 |
| IV | 90° to opt. . . . | 13·87 | 10·40 | |
| | Shear (optimum) | 10·4 | — | |

facturers of such well-known products as Durisol, Permali, Jicwood, etc. It is, nevertheless, a most important consideration as the designer can specify the grade of wood most suitable for the stresses and strains to be encountered in service. This naturally facilitates production and ensures high efficiency of results. A point which is rightly stressed by Colonel Clark is that the specific gravity of the material may be accurately controlled within 3 per cent. plus or minus, so that there is no chance of there being uneven distribution of weight.

The entire fuselage of the "Clark 46" is made up of two large mouldings of Duramold $\frac{5}{32}$ in. thick, reinforced by transverse ribs and stuck together by means of a special synthetic resin adhesive. The surface of the moulding is smooth and free from all protrusions, so that there is a considerable reduction in drag and a marked improvement in efficiency. Of great importance is the fact that the moulded fuselage is more rigid than one fabricated of metal owing to the greater thickness of the walls. This increase in thickness renders the machine better able to resist stresses in compression and the Duramold fuselage will, it is stated by Colonel Clark, support a compressive load 14 times as great as a similar one made of reinforced Duralumin. In his article in *Aero Digest*, the inventor emphasised that thin sheet is inherently an inefficient medium for construction.

A plate in which the ratio of length in the direction of the applied compressive load to the thickness of the plate is high, buckles under

compression and, after buckling, is incapable of supporting a load of any magnitude. The deflection in buckling under a given load varies inversely as the elastic modulus of the material, and by the basic theory of moment and inertia, roughly, inversely as the cube of the thickness of the materials.

According to tests carried out, Duramold is approximately 50 per cent. better than 17ST Duralumin in fatigue resistance, based on allowable stress for equal weight per unit area. No creep occurs and the material has excellent energy-absorbing properties. When tested under very sharp temperature changes, Duramold stood up remarkably well and no adverse effects were found. Moisture absorption of less than 1 per cent. in twenty-four hours' immersion is reasonably good.

So far Duramold has only been used for moulding large pieces, such as the fuselage of experimental planes, but it is suggested that complete wings could be moulded, also elevators, rudders, ailerons, cowling and fairing pieces. It is not, however, suitable for landing gear or control systems.

Of more recent date is the Timm Trainer, a two-seater open tandem monoplane constructed throughout of a triple criss-cross laminated spruce plywood heavily impregnated with a solvent solution of phenolic resin. The process of manufacture, as briefly explained in a press release by the Timm Aircraft Corporation of California, U.S.A., consists of pre-forming the desired shapes from the dry impregnated sheets of plywood (uncured) and then curing them under heat and heavy pressure. Sealing and bonding of the edges is carried out by the use of phenolic adhesive polymerised by locally applied heat and pressure.

The great advantage of the use of impregnated wood for constructional purposes in war-time is that it enables parts to be mass produced, although previously it has been stated that mass production is not desirable owing to the extremely fluid state of designs. There is, however, a considerable amount of latitude permitted in the fabrication of parts and no doubt modifications would be much simpler to carry out than in the case of all-metal structures. An important point in favour of laminated wood is that it can easily be repaired on the field by the use of unskilled labour, whereas, of course, metal requires the attention of skilled metal-workers.

The advantages which can be claimed for impregnated wood

in the construction of large parts may be summarised as follows :

1. Good mechanical strength. (In the form of a thin-walled cylinder of given weight under compression Duramold is approximately 10·4 times as strong as stainless steel, 3·4 times as strong as aluminium alloy and 12·1 as strong as reinforced solid phenol-formaldehyde resin).
2. Good fatigue resistance. (50 per cent. better than 17ST Duralumin.)
3. Smooth finish and freedom of moulded parts from drag.
4. Non-combustible.
5. Low moisture absorption. (Less than 1 per cent. in twenty-four hours.)
6. Comparative ease and speed of fabrication.

Apart from large moulded parts, such as fuselage and wings previously mentioned, use is also made of both impregnated and compressed wood for spars and various electrical parts. Probably the most important application so far found is for fixed and variable-pitch airscrews, where this material is now frequently used for the root of the blade. The Schwarz type of blade is the best-known wooden type employing an impregnated hardwood core and this has a tensile strength of 16 tons per sq. in. The method of manufacturing the blade is roughly as follows :

Sheets of impregnated compressed wood are cut to size and spliced and glued to spruce boards with a long scarf joint so as to make a board which is composed of laminated spruce over the greater part of the length and laminated compressed at one end. After cutting to the required size the impregnated wooden root is threaded and screwed into a metal ferrule and the spaces left by the screwed parts filled up with a special self-hardening and non-shrinking composition forced in under high pressure. The blade is then covered with the acetate protective coating and the leading edges protected by means of strips of metal.

The weights of blades, as given by Airscrews Ltd., are as follows :

| H.P. | Number of Blades. | Airscrew Diameter (ft.). | Weight of each Blade (lb.). |
|---|---|---|---|
| 240 . . . . | 2 | 7·9 | 18·25 |
| 900 . . . . | 2 | 10·3 | 41·15 |
| 575 . . . . | 2 | 11·5 | 46·2 |
| 660 . . . . | 3 | 11·9 | 44·0 |
| 730 . . . . | 3 | 12·8 | 48·9 |

### Special Reinforced Synthetic Resins.

Apart from impregnated and compressed wood, increasing use is now being made of reinforced plastics and a great deal of research work has been done on their properties. The most widely used plastics of this class are the laminated sheet materials, particularly those with laminæ of paper and fabric. These find applications for instrument-panels, switchboards, general electrical parts, gears, pulleys, etc. Decorative veneers are also being used for decorating commercial craft, such as the *Yankee Clipper*, in which Micarta is generously employed for table-tops, wash-basin surrounds or splash backs and other less important purposes. Applications have also been found on the *Clipper* for other types of plastics for lampshades, switches, knobs, signs, wall decoration, etc. The advantage of decorative veneers for aircraft is that, quite apart from its merits as an artistic decorative medium, it is light in weight and combines strength with rigidity.

It is likely that greater use will be made in the near future of laminated tube for conduits and ducts, now made of Duralumin or acetate. Although laminated sheet cannot compete with acetate as regards workability, it has the advantage of possessing greater rigidity and superior electrical properties. There is no reason why both acetate and laminated material should not be used together, where, for instance, a moulded shape is needed in connection with a straight line of ducting.

Advantages which can be claimed for laminated sheet material are:

1. Low specific gravity (approx. 1·40) in comparison with metal.
2. Good mechanical properties.
3. High dielectric properties.
4. Low moisture absorption.
5. High resistance to corrosion.
6. Excellent machining properties.

The main disadvantage of the material is that it cannot be formed in the same way as thermo-plastics or moulded under pressure to the same extent as thermo-setting resins. On the other hand, preforming is possible, using uncured sheets and later curing them under heat and pressure. The thin sheets, $\frac{1}{32}$ in., can be punched cold and a large number of such punchings are used for electrical work.

Dr. N. A. de Bruyne has spent a great deal of time on developing new reinforced plastics for use in aircraft construction and his Gordon Aerolite, a special linen reinforced phenol-formaldehyde resin, is the nearest approach yet made to a material possessing comparable strength to metal. In a lecture given by Dr. de Bruyne to the Weybridge Branch of the Royal Aeronautical Society in January, 1939, he stated that to secure uniformity and keep to the specification figures the flax fibres have to be uniformly arranged parallel to one another. This is done by a special machine, which takes in loose fibres, draws them into a uniform band and then passes this band through the impregnating bath, after which it is dried and is ready for pressing. This is carried out by passing the material in a trough about 30 ft. long by 6 in. wide through an 800-ton hydraulic press. The trough is electrically heated and so arranged that the temperature is high during the operation of moulding and remains at a high temperature after the trough has passed through the press. The press has two rams, one at the top and the other at the side. The latter is designed to give lateral support to the trough, the actual moulding being done by the top ram.

Dr. de Bruyne is of the opinion that the future of large-scale use of plastics in aircraft construction lies in the use of standard materials, such as the planks of Gordon Aerolite, which can be fabricated by any aircraft manufacturer into structures of any size or shape, using only the simplest tools. He does not consider it would be feasible, or, indeed, advisable for aircraft concerns to expend many thousands of pounds in laying down large and powerful presses for moulding plastic parts, such as fuselages, wings, etc., as these would have to be scrapped after what might be only a short run, whereas by using planks or other standard shapes of plastics, fabrication could be carried out with existing machinery without any dislocation of production or unnecessary expenditure.

It is very encouraging to consider the great progress made in the development of a plastic possessing many of the characteristics required for highly stressed constructional materials. The latest flax reinforced phenolic resin produced by Dr. de Bruyne is not only extremely strong, but on a strength to weight basis definitely superior to the other competitive constructional materials, such as aluminium, duralumin, elektron and even steel. In an article by Dr. de Bruyne in *Aircraft Engineering*, May, 1940, the author states that in the range of long struts, thin struts and lightly loaded struts the organic materials are supreme. As the load to be carried increases in proportion to the size of the strut, however, the proof stress begins to become of significance and the discrepancy between metals and wood becomes smaller; until finally in very short struts the metals are superior because proof stress/specific gravity is then the figure of merit.

The following figures are illustrative of the excellent physical properties possessed by Dr. de Bruyne's plastics. It may be added, however, that the authors understand that Gordon Aerolite has been much improved and that the latest figures are much greater than those given below.

| Material. | $t$ Tensile Strength (lb. per in.$^2$). | C Comp. Strength (lb. per in.$^2$). | E Young's Modulus (lb. per in.$^2$). | S Shear Strength (lb. per in.$^2$). | $\rho$ Specific Gravity. |
|---|---|---|---|---|---|
| Cord material . . | 25,000 | 27,000 | $2{\cdot}4 \times 10^6$ | 5·800 | 1·34 |
| Gordon aerolite . | 45,000 | 24,000 | $6{\cdot}0 \times 10^6$ | 5,000 | 1·43 |
| Duralumin . . . | 55,000 | 55,000 | $10{\cdot}0 \times 10^6$ | 30,000 | 2·8 |
| Spruce . . . . | 10,000 | 5,000 | $1{\cdot}3 \times 10^6$ | 750 | 0·5 |
| Steel . . . . | 180,000 | 180,000 | $30{\cdot}0 \times 10^6$ | 105,000 | 7·8 |

| Material. | $t/\rho$ (lb. per in.$^2$). | $C/\rho$ (lb. per in.$^2$). | $E/\rho$ (lb. per in.$^2$). | $S/\rho$ (lb. per in.$^2$). |
|---|---|---|---|---|
| Cord material | 18,700 | 20,160 | 1·79 | 4,330 |
| Gordon aerolite | 31,500 | 16,800 | 4·20 $10^6$ | 3,490 |
| Duralumin . | 19,700 | 19,700 | 3·57 $10^6$ | 10,700 |
| Spruce. . . | 20,000 | 10,900 | 2·60 $10^6$ | 1,500 |
| Steel . . . | 23,100 | 23,100 | $3{\cdot}85 \times 10^6$ | |

There seems little doubt that this type of reinforced resin will

find important future applications for stressed parts where the physical advantages of the resin can be exploited to the best possible advantage. The important point to remember in connection with these low density materials is that a sufficient range of plastics is available for the designer who can thus make the best possible use of them for applications where they are well fitted.

Another form of plastics possessing excellent physical properties which is attracting the attention of aircraft manufacturers is the use of resin boards and blanks made by standard paper-making processes. According to R. E. Brannan, Sales Engineer, Bakelite Corp., *Modern Plastics* Catalog, October, 1939, the method is known as " wet machine " manufacture and produces a pulp board of any desired thickness which is thoroughly impregnated with the resin (probably in the form of an emulsion). The resin board may be employed either in sheets or punchings. The following are the principal physical properties of the material in moulded form :

| | |
|---|---|
| Specific gravity . | 35 |
| Tensile strength . | 3,000 to 11,000 lb. per sq. in. |
| Modulus of elasticity . | (1·1 to 1·6) by $10^6$ lb. per sq. in. |
| Impact strength . | Energy to break with grain, 0·8 to 1·0 ; across grain, 0·3 to 0·45 ft.-lb. |
| Water absorption . | Gain in twenty-four hours, 0·3 to 0·5 per cent. |
| Heat resistance . | Not recommended for use where heat exceeds 302° F. |

It is of interest to note that a sheet material made by a somewhat similar process, using an aniline synthetic resin for impregnating purposes, is finding important uses in Great Britain for special electrical purposes.

Another material of potential interest to aircraft manufacturers is the flock impregnated resin similar to the German Peton and the British Hy-Ten products. These are made by impregnating flock with an emulsion of synthetic resin and their most important characteristic is an exceptionally high impact strength, this being given as 25 cm. kg. per cm.$^2$. Tensile strength is 23,000 lb. per sq. in. ; compressive strength 25,000 and shearing strength 18,000 lb. per sq. in. Water absorption is low at 0·8 per cent. in twenty-four hours. Some experiments have been carried

out with Hy-Ten (which possesses somewhat similar characteristics to Peton) in the moulding of aircraft seats. The material is first preformed into the correct shape and this is then subjected to very heavy pressure and heat to effect the cure. So far these materials have found their principal applications in the electrical industries where high dielectric strength must be coupled with the best possible mechanical strength. Whilst it is not suggested that it would be possible to make extensive use of this type of material for elaborately designed or very deep draw mouldings, owing to the relatively poor flowing qualities of the material, there seems little doubt that aeronautical uses could be found where the excellent physical qualities could be exploited to advantage.

**Standard Moulding Powders.**

Phenol-formaldehyde moulding powders with wood flour or fabric fillers are not used to any great extent in aircraft construction, except, of course, for the many small accessories and fittings needed in the equipment of the aeroplane. Probably the most important are the moulded pulleys which carry the control wires. These are now being widely used and give smooth and trouble-free service, as they cannot be corroded and do not bite into the wire. Instrument cases, frames of special electrically heated goggles used during high-altitude flying and various parts of the electrical system are also moulded of standard phenolic moulding powders. Urea mouldings are not used to the same extent as the phenolics and find their principal applications for decorative purposes, such as lamp covers and shades, control knobs and similar items, making use of either transparent and translucent material, as well as light pastel shades in the opaque.

The tendency at the present time seems to be that aircraft manufacturers prefer to use thermo-plastics, particularly acetate, wherever possible and, in consequence, many pieces of equipment previously moulded of phenolic resin are now being moulded or formed of acetate. One disadvantage of phenolic mouldings, and this applies also to urea, is that damaged pieces cannot be satisfactorily repaired, whereas, of course, acetate can easily be cemented and the broken parts welded together to make a joint as strong as the undamaged material. There are, of course, many applications where the rigidity, surface hardness and dielectric properties of the thermo-setting resins are absolutely essential.

### Synthetic Glues.

Increasing use is now being made of both liquid and solid synthetic adhesives, particularly the sheets of thin tissue paper impregnated with phenolic resin and sold under such well-known trade names as "Tego Film" and "Plybond." The best-known urea glues are Kaurit and Aerolite, both of which can be used in the cold as well as by the hot pressing method. Methods of employing these resin glues are explained in the chapter dealing with "Furniture."

### Synthetic Rubber.

It is, perhaps, only natural that rubbery materials, such as Neoprene, Thiokol, Buna, etc., should find several important applications in aircraft construction, where resistance to petrol and oil, coupled with good mechanical properties, are the main essentials.

Probably one of the earliest major applications found for synthetic rubber in the aircraft industry was on the Pan-American *China Clipper* for sealing fuel tanks situated in the wings of the plane. The particular type of synthetic rubber preferred for this purpose was Thiokol, which, incidentally, is a U.S. Army Corps Specification for all fuel hose and is also employed for impregnating fabric for balloons.

All types of synthetic rubber are widely employed for hose, oil seals, gaskets, washers, etc., choice of rubber being mainly influenced by the particular requirements of the application. Thus, some types of synthetic rubber and new rubber-like plastics, such as Koroseal, the vinyl polymer manufactured by B. F. Goodrich Co., U.S.A., have a very rubbery nature, e.g. Buna S, and also possess high tensile strength and good elongation at break, whilst others are not so rubbery, e.g. Thiokol, which possesses fair tensile strength, fair elongation at break, but is very resistant to oils, solvents and oxidation. Neoprene is not as rubbery as Buna S, but more so than Thiokol. It is very strong, has good elongation at break and is very resistant to oil, etc. Koroseal, which is not a true synthetic rubber, only a rubber-like plastic, is not quite as rubbery as the true synthetics, although, like rubber, it is practically non-compressible.

Synthetic rubber is also used for sheathing cables for use in

aircraft and is superior to rubber for this work. Another interesting application is the use of rubber-like plastics for sheathing the heavy wire cables required for mooring the balloon barrages. The writers understand that vinyl polymers are the most suitable for this purpose, on account of their exceptionally high dielectric properties.

APPLICATIONS OF CELLULOSE ACETATE MATERIALS IN AIRCRAFT CONSTRUCTION

| Transparent Sheet. | Black Sheett | Coloured Sheet. | Black Tube. | Powder. |
|---|---|---|---|---|
| Hoods<br>Windows<br>Turrets<br>Fairings<br>Coverings of airscrew blades (Schwarz)<br>Bomb doors and inspection doors<br>Map cases<br>Camera window draught shield<br>Labels | Fairings for strut ends<br>Fillets for tail-planes, fins and wing roots<br>Spats<br>Scoops<br>Cabin heating ducts<br>Slats<br>Wing tips<br>Dinghy stowage boxes<br>Spinners<br>Pilot seats<br>Chutes for empty cartridge links<br>Radio mast fairing<br>De-icing for radio aerial | Navigation lights | Conduits<br>Smoke flare tubes<br>Petrol jettison pipe system and outlet<br>Air chute for cabin heating | Lamp covers<br>Controls<br>Switches |

APPLICATIONS OF ACRYLIC RESIN

*Sheet Material.*

| | |
|---|---|
| Hoods | Turrets |
| Windows | Fairings |

APPLICATIONS OF OTHER TYPES OF PLASTICS IN AIRCRAFT CONSTRUCTION

| Compressed and Impregnated Wood. | Laminated Sheets (Paper and Canvas Laminæ). | Phenolic Mouldings. | Urea Mouldings. | Styrene Mouldings. |
|---|---|---|---|---|
| Roots of wooden blades<br>Moulded fuselage of "Clark 46"<br>Moulded fuselage and wing of "The Timm Trainer"<br>Flooring<br>Gear wheels<br>Hand wheels<br>Masts for pilot head and aerials | Pulleys<br>Instrument boards and brackets<br>Pilot seats<br>Hand wheels<br>Gear wheels | Pulleys<br>Instrument boards and brackets<br>Electrical and radio parts | Lamp covers<br>Instrument dials<br>Control switches | Electrical and radio parts |

# CHAPTER VIII

## MOTOR-CAR MANUFACTURE

DURING the last five years increasing use has been made of plastics in motor-car construction and it is claimed that at least 10 lb. of mouldings are needed for the popular 8 or 10 h.p. car. This bulk is made up of facia boards, window fillets or frames, windscreen pillars, control knobs, dash controls, glove compartment doors, covering for steering wheels, horn buttons, ash trays and various insulating parts used for the electrical side of the car mechanism.

The main advantage which can be claimed for plastic parts, apart from price, which will be considered later, is reduction in weight as compared with metal. Ordinary pressed steel has a specific gravity of approximately 7·8, whereas phenolic resin is approximately 1·4, that is, nearly six times as light. This difference in weight may well be instanced by the fact that a moulded facia board 3 ft. 3 in. in length weighs only 3½ lb., whereas a metal one of the same dimensions would probably weigh nearly 20 lb. The motor-car designer realises the importance of this reduction in weight and it encourages him to make changes in design so as to exploit the economy to full advantage.

Apart from the considerable reduction in weight made possible by the substitution of plastic for metal parts, there are other important advantages which can be claimed for mouldings. These may be briefly summarised as follows:

1. Improved appearance resulting from the use of a material with a permanently coloured and high-polished surface. Unlike sprayed metal, the moulded surface never sheds its colour and, moreover, the plastic colour is reasonably fadeless.
2. Sound and heat insulation. Increasing importance is now being attached to these factors as it is realised that they tend to improve the comfort-giving properties of the car.

3. The plastic surface is pleasant to the touch, being never as cold as metal. This is due, of course, to the low heat conductivity of plastics.

Coupled with these rather obvious advantages, ease of fabrication and absolute accuracy of finish must be taken into account. Choice of a material that can be produced in two operations, that is, moulding and polishing, instead of something like half a dozen or more in the case of metal, represents a considerable saving in time as well as money. Improvements in the design of both compression and injection moulding machines, which renders them more automatic and capable of handling larger mouldings, will tend to make plastics of even greater value to the motor-car manufacturer in the near future.

Turning now from the practical advantages resulting from the wise use of plastics in motor-car construction, it should be realised that the main reason why these materials are at present used by the manufacturer is because they are slightly cheaper than metal and not because they are in any way more suitable for the purpose. This short-sighted policy, which is, unfortunately, only too common in modern business circles, is definitely bad, bad for the manufacturer as well as the moulder. It is not realised that there exists to-day such an extensive range of plastics that a strong case can be made out for using moulded fittings solely on their merit. Apart from the all-familiar " ash-tray " mottles and dull shades of brown, the phenolic type of resin is available in an extensive range of solid colours ; the ureas in white, ivory and delicate pastels and cellulose acetate, which may be moulded over die castings, in an even more catholic selection of colours. The surface may be embellished with metal inserts, embossed or engraved, sprayed with lacquer and even metallised by a new and promising electrolytic deposition process. The last-named method of decorating is particularly promising, as many people prefer the look of a metallic surface to a moulded one, which often has a very heavy and solid appearance. Metallised plastics, that is mouldings completely covered with a thin deposit of metal, say $\frac{1}{2000}$ in. thick, or merely decorated with bands of metal, offer great promise for facia boards, door-handles, radiator-caps, gear-levers, controls and many other parts.

According to motor-car salesmen, and they have their finger on

the pulse of public opinion, the would-be customer is not altogether favourable to the presence of large moulded parts in a new car. Indeed, it is suggested that their presence is a confession that the manufacturer is trying to " put over " an inferior production. This impression is unfortunate, but it is, nevertheless, to be taken into account and is the main reason why manufacturers of luxury cars often give euphemistic names to the plastic parts and are extremely reluctant to admit that they are plastic or of similar origin.

Public antipathy towards the presence of plastic parts in motor construction is not altogether fanciful and can often be traced to the results of actual experience with either window fillets that have snapped as the result of vibration or moulded facia boards that have cracked through the pressure exercised by dimensional changes. These are some of the factors responsible for the building up of a prejudice towards plastics.

Neither the moulding-powder manufacturer nor the moulder can be held responsible for the conditions mentioned above. The motor manufacturer is himself solely responsible, as the margin which his costing department allows for mouldings purchased from the trade is barely sufficient to ensure uniform quality. The moulder who accepts the order, and he frequently does so merely to keep his plant working and to reduce overheads, must of necessity use the cheapest moulding powder and adopt the quickest, but not always the best, methods of production. In fact, it is no exaggeration to say that very often the whole policy of the motor-car manufacturer seems to be designed not to produce good work. The writers know of one large body builder who has cut the price paid for mouldings to such an extent that the moulder cannot even afford to pack them securely in boxes and he is, therefore, forced to dispatch them in open crates. Needless to say, this method of packing results in an abnormally high percentage of breakages. This question of waste is a disturbing one because in the fitting of window fillets and other parts to the body a large number of breakages occur, due to the fact that the material is so brittle that it cannot withstand the pressure set up by screws pushed home a little too far. In cases where holes are drilled in the moulding, and this is sometimes preferred to the use of more complicated and costlier tools which would ensure the production of parts complete with holes ready

for dropping in the screws, then breakages are always liable to occur.

Increasing use is now made of self-tapping screws, which largely eliminate the insert problem where holes of $\frac{3}{16}$ in. diameter, or less, are required. In the *Ready Reference for Plastics*, compiled by Boonton Molding Company, U.S.A., the following advantages for self-tapping screws are mentioned :

1. Elimination of the moulding of inserts and the cost of the inserts.
2. Increased production from the die.
3. Uniformity of holding power.
4. Stronger grip.
5. Elimination of crossed threads in inserts. Brass threads usually have to be cleaned of flash.

**Design and Plastics.**

The authors are of the opinion that the most effective use that can be made of plastics for interior fittings is not in the form of large mouldings, such as the completely moulded facia board, but, following current American practice, the wise co-operation of plastics and metal die castings. Cellulose acetate has greater possibilities than the thermo-setting resins on account of its wider colour range, superior finish and greater toughness. It is, indeed, a material in every way fitted for hard service, and yet it has all the qualities which make it attractive to the feminine eye. The complaint which is quite frequently levelled against the large phenolic moulding is that it looks cold, heavy and artificial. Strangely enough, it is neither cold nor heavy, although it is certainly artificial ; but this damning impression, no matter how false it may be, is one which must be taken into account by the designer : yet it is only made in the case of large moulded surfaces which are not broken up or relieved in any way This leads one to the belief that for the interior of the car large moulded surfaces should be avoided, or where unavoidable, some attempt at decoration should be made, such as metal inserts, metallising or even partly spraying with cellulose dope. It is no exaggeration to say that the ability to obtain large mouldings is a temptation to manufacturers to sacrifice monotony and mediocrity of finish for economy and ease of assembly. Probably only in the case of the

jewel-like cast resin is it possible to obtain a large facia board which loses nothing by being large. The writers consider that the Catalin instrument panel and fittings in the Bentley, exhibited at the 1938 Motor Show, to be one of the few examples where size was an asset. The unusual colour and fine finish of this casting were shown off to good advantage and it was certainly generally admired by the trade. Few, however, guessed that it was a plastic.

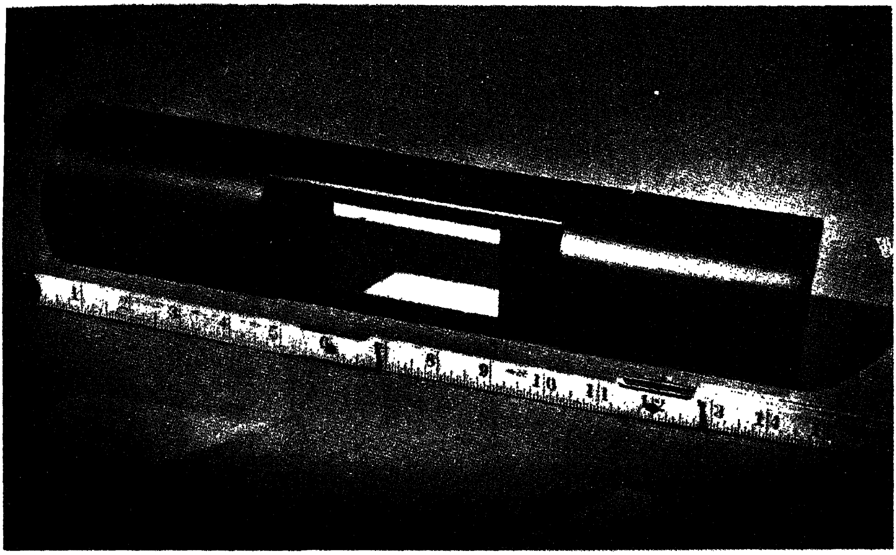
**Future Developments.**

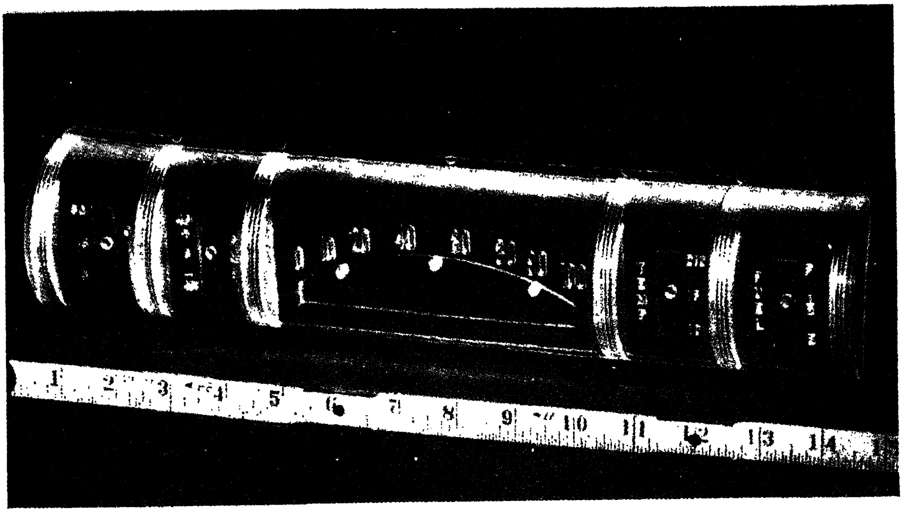
Very little appears to have been done in this country with really large pressings, but in Germany the Auto Union Aktien Gesellschaft have made considerable progress in the production of motor-car bodies wholly or partly made of large mouldings. One of the writers examined a car door moulded of special shock-resisting resin at the Leipzig Spring Fair in 1939, and it is understood that the German People's Car, a few models of which were said to exist prior to the outbreak of war, contained an increased amount of plastics. In an English patent, No. 492,630, the Auto Union describes a vehicle body comprising preformed units of synthetic resin saturated material and preformed reinforcing members of similar material which are assembled in a casing with adhesive applied at the joints.

The progress made in the development of an all-plastic motor body in Germany must be accepted with considerable reserve because, as the motor industry in the Third Reich is, or rather was at the time of the war, heavily subsidised by the Government who obviously encouraged the use of plastics in preference to metals, it is impossible to arrive at any real decision regarding the economics of the plastic shell or body. It is useful, however, to consider quite briefly the advantages and disadvantages of all plastic bodies.

*Advantages.*

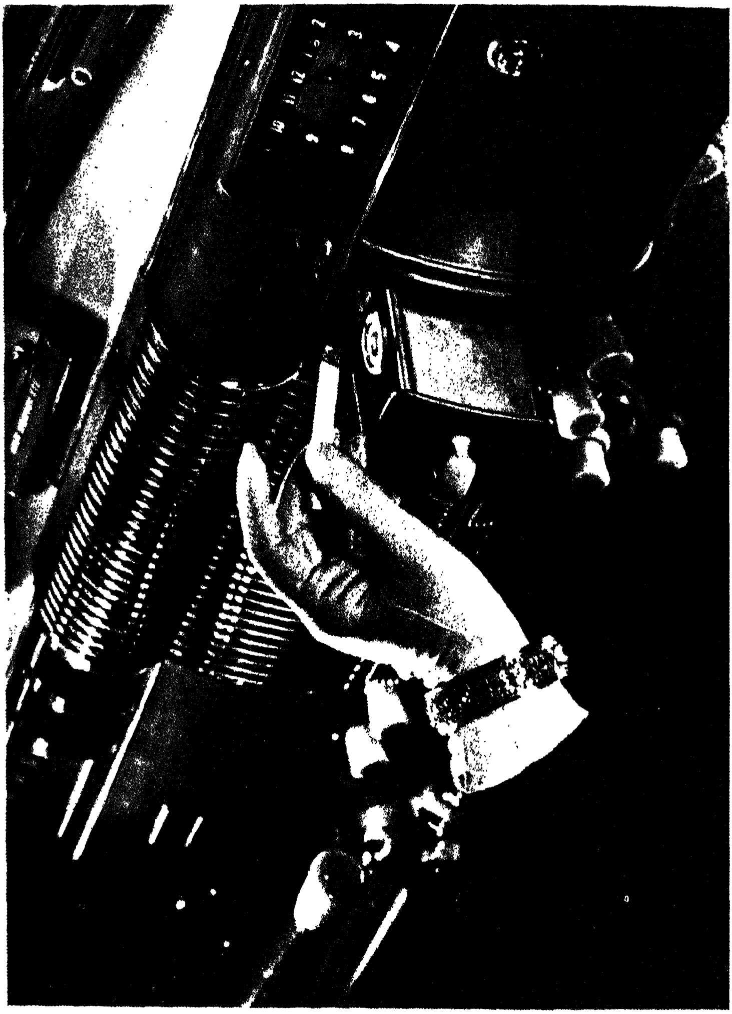
1. Considerable reduction in weight, which would mean not only a better performance, but the fitting of larger bodies for smaller engines. Use of a light-weight material for the body would undoubtedly result in revolutionary changes in design.





ABOVE: Nash glove-compartment door.
BELOW: Nash instrument board of transparent plastics.

[*Facing p.* 116.



The Nash automobile fitted with an instrument panel of Tenite II (cellulose acetate-butyrate).

*Facing p.* 117.]

2. Improved sound and heat insulation and therefore greater comfort.

*Disadvantages.*

1. Greatly increased cost of material in the case of high-strength resins.
2. Reduction in strength, which may be quite considerable.
3. Long-cycle curing, which may disturb the flow of work and increase overheads.
4. Difficulty of joining units together so as to effect a really strong joint.

Probably the greatest obstacle to the employment of plastics for body-work is that it would mean the scrapping of expensive and extensive steel-pressing plant, and the installation of even costlier hydraulic presses requiring heat for the moulding of plastic parts. Another obstacle is that both shock-resisting resins and also laminated sheet material, suitable for large pressings, are only available in dull browns, and to render the surface really attractive, spraying with cellulose dope would be necessary. Indeed, the moulded door shown by the Auto Union at the Leipzig Fair was sprayed to conform to the rest of the body-work. Even spraying cannot hide the surface imperfections of large moulded surfaces and the finished result is bound to be very much inferior to the highly polished and mirror-like appearance of the lacquered steel body.

This somewhat damning indictment of the plastic motor body does not mean that the writers consider that future uses of plastics will be confined to small fittings. It is, however, their opinion that present-day high shock-resisting resins or, indeed, laminated sheets are not ideal for really large-size pressings for the reasons stated above, but future development may reveal a type of thermoplastic which could be made to flow evenly and smoothly over large surfaces of a mould and to suffer little in comparison with sprayed pressed metal sheeting.

A significant portent for the future is the work now being carried out by the Ford Motor Co., at Dearborn, U.S.A., with soya-bean plastics, which have for some years now been extensively developed by Mr. Ford. According to Wm. T. Cruse, *Modern Plastics*, January, 1940, soya-bean plastic, which was first used to produce

distributor and coil cases, is now being used by Ford to mould accelerator pedals and, experimentally, rear deck doors, the largest mouldings so far produced at Dearborn. Seats for Ford tractors are also made of reinforced soya-bean plastic; in this case the problem was solved by using a papier-mâché contour impregnated with bonding material. Trunk compartment doors for Ford Mercury cars are also being moulded experimentally on 1,200-ton presses at the Ford Plant. Almost the entire surface, nearly 3 ft. by 4 ft., is curved in contour and the piece preformed before pressing.

Very little information appears to be available about soya-bean laminated or reinforced resin and yet it is, probably, this type of plastic that one must look to for really large pressings, such as would be required for building up complete car bodies. Although soya-bean plastic does not represent any great improvement on standard phenolic resin, yet it has the very great advantage of being both cheap and plentiful. According to recognised authorities on the subject, a straight formaldehyde hardened soya-bean meal costs only 5 cents a pound compared with something like 17 cents a pound for phenolic resin. The difference is enough to justify plenty of development work. In practice, of course, the straight soya-bean plastic is seldom used alone, but usually in conjunction with a phenolic resin and various other ingredients calculated to endow the mixture with certain properties. Still, even this blended plastic is one of the cheapest yet available for the motor manufacturer. It should be realised, however, that soya-bean plastic is not the only plastic obtained from the farm. Zein from wheat offers great promise for the future and we shall, no doubt, hear a good deal about this during the next few years, especially when there is a very large surplus of wheat.

Some of the new lignin plastics are not without promise as being cheap and plentiful, particularly lignin-sulphur resins which are thermo-plastic and have a very high glossy finish. According to information contained in an article on "Chemical Utilization of Wood Wastes" in the September, 1939, issue of *Pacific Chemical and Metallurgical Industries*, lignin combines with 1–2 per cent. sulphur to form a thermo-plastic material that is hard, capable of taking a high polish, has a fair degree of elasticity (approx. 52,000 kg. per sq. cm.) and has a strength comparable to com-

mercial plastics (modulus of rupture 510–555 kg. per sq. cm.). It requires no great prophetic powers to foretell that, as these new resins can be made from all types of wood waste, they will eventually be cheap and plentiful and therefore worthy of consideration by manufacturers with very large turnovers of plastic components. Probably before long, interesting results will be announced from Dearborn regarding the all-plastic moulded car body as information reaches us (April, 1940) that Bakelite Corp. U.S.A., are collaborating with Ford in the development of the first complete plastic body.

Apart from large-size mouldings, several ideas present themselves as being quite feasible, particularly for laminated wood. For instance, laminated sheeting made up of paper laminæ could be used for the backs of the front seats and even for the sunshine roof. Incidentally, there is no reason, apart, of course, from cost, why cellulose acetate or acrylic resin should not be used for the sliding roof. This would have the great advantage of allowing light to be transmitted, even though the weather were not suitable for sliding back the roof. Acrylic resin, such as Perspex, is, of course, the ideal material, owing to its extremely good light transmitting properties, but cellulose acetate would serve the purpose very well.

Another possible application for plastics is for door-handles. If moulded of Peton or Hy-ten, two well-known flock-filled resins, the moulded handles would be well able to give full satisfaction and stand up to shocks and vibration experienced in normal service. Peton, for instance, has an impact strength of 25 cm. kg. per $cm.^2$; shearing strength, 18,000 lb. to sq. in.; compressive strength, 25,000 lb. to sq. in. and tensile strength 23,000. This compares favourably with the strength of the metal die castings generally used for door-handles.

Plastics do not possess the high strength of metals when compared without any regard to the great difference in the specific gravity of the two materials. When, however, the strength/weight ratios of plastics and metals are compared, then plastics do not appear to be so far behind. In an article in *Plastics*, by E. E. Halls, May, 1939, the following strength/weight ratios are given: 2·1 for moulded phenolic plastics, 7·1 for magnesium, 2·6 for zinc and 3·3 for aluminium: these being the metals generally used for die casting.

## Moulded Pistons.

On the mechanical side, plastics have been tried out for various applications, most of which, however, do not appear to have gone beyond the experimental stage. Some very secret work has been carried out with plastic pistons, the main idea being to make possible a worthwhile reduction in weight with corresponding increase in efficiency, but practically no information is available regarding the progress made. The difficulties facing the manufacturer of a moulded piston able to give a performance in any way comparable with one made of a suitable aluminium alloy are considerable. Apart from the extremely low heat conductivity of phenolic resin and the consequential difficulty of dissipating the heat, the strength and surface hardness of the moulding would not appear to be comparable with metal. There is also the question of finish. The writers are somewhat doubtful whether it would be possible to obtain a moulding with the necessary mirror-like finish or, indeed, one accurate to the extreme limits required for maximum efficiency. It is useful to compare the main physical properties of an aluminium alloy used for motor-car pistons with a standard phenol resin (asbestos-filled).

| | Aluminium Alloy. | Asbestos-Filled Phenolic Resin. |
|---|---|---|
| Tensile strength (tons per sq. in.) | 15–18 | 5,000–10,000 lb. per sq. in. |
| Brinell hardness | 105–140 | 30–45 (25 kg.). |
| Co-efficient of expansion per ° C. | 0·000024 | 0·000025–0·00004. |
| Co-efficient of thermal conductivity | 0·35 | 0·0008–0·0020. |
| Specific gravity | 2·9 | 1·70–2·09. |

The noticeable differences are the tensile strength and thermal conductivity. In the case of the former aluminium alloy is nearly seven times stronger, and in the case of the latter the alloy is definitely superior to the extent of over 400 times. It has been suggested that the presence of metal inserts would render possible the dissipation of heat and may be this device may help to solve the problem.

## Plastic Distributor.

Whilst the use of plastics to replace metal for pistons is a somewhat doubtful proposition, although, naturally, one of great

interest to engineers, there are other applications where plastics are more obviously suitable. Distributor caps are being moulded of paper-filled phenolic resin and apparently give satisfaction. Experiments indicate that transparent ones moulded of polystyrol resin might prove welcome. Apart from the transparent nature of polystyrol, it possesses very high dielectric properties and is obviously a material well fitted for the purpose. The fact that the cap is transparent would permit a clear vision of working conditions and reveal excessive arc-ing across points, tracking between pick-up contacts, faulty timing, etc. Polystyrol is a more suitable material than transparent amino resin and experiments with the latter material have not been altogether successful in practice.

**Fans.**

Another potential application of plastics is for fans, either fabricated of laminated sheet or moulded of paper-filled phenolic resin, preferably the former for greater durability. These fans, or rather the actual blades, would prove more costly than similar ones made of metal, but they would certainly prove more immune to the corrosive effects of moisture and possess a longer trouble-free life. Coupled with an ability to resist corrosion, the plastic fan would be lighter than the metal one and therefore, in theory at least, more efficient. Apparently cost is the main factor preventing the use of plastics for this purpose, and manufacturers argue that the costing system, as applied to mass-produced cars, is so rigid that it does not allow for the use of a more expensive material than metal for even such a small item as a cooling fan.

It has been suggested that a moulded case could be used to advantage, instead of the metal one now employed for the air cleaner and silencer. This seems a possible application, as undoubtedly the moulded container would be not only lighter in weight but less liable than metal to transmit vibration and rattle.

Two years ago Lagonda Motors Ltd. made a novel use of plastics for their Le Mans Model. A phenol-formaldehyde moulding was used as a distance piece between the base of the oil pan and the sump, having the studs running through it. The aim of the designer was to deepen the sump so as to obtain better cooling and greater oil capacity. Apparently this device proved

quite successful in use as the two cars fitted with mouldings put up a good performance in the race.

**Gears.**

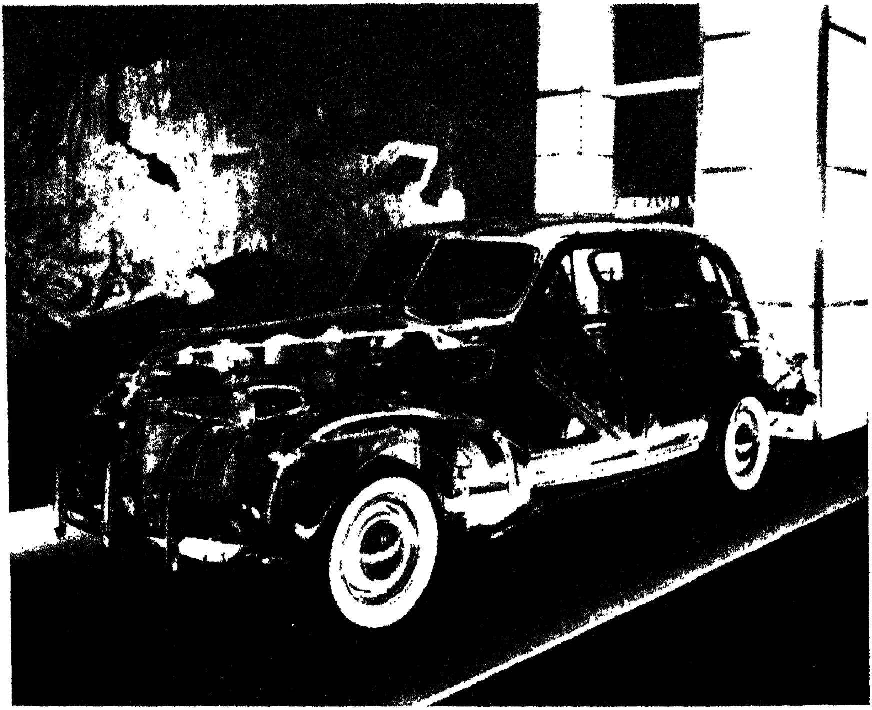
Timing gears cut from laminated sheet have proved very successful and it is now generally recognised that this non-metallic material has many important advantages over metal. It reduces transmission noises to a minimum and possesses an elasticity sufficient to absorb shocks and intermittent stresses liable to break down metal gears. Of great importance also is the fact that laminated sheet material is able to resist corrosion far better than metal and therefore has a longer life to compensate for its increased cost. From the works standpoint it should be pointed out that laminated sheet is readily adaptable to standard machine-tool methods of working and it can be turned, drilled, shaped or milled, etc., with standard equipment.

**Moulded Mudguards.**

Moulded mudguards for motor-cars are not yet practical, owing to the large dimensions required, but they are in use on motor-cycles and apparently give satisfaction in service. They are usually moulded of either celluloid or cellulose acetate. Advantages which can be claimed for these are considerable :

1. Reduction in weight ; the cellulose acetate mouldings being nearly six times lighter than mudguards made of sheet metal. Celluloid works out a little heavier than acetate, but is still only one-fifth the weight of pressed steel.
2. Permanent colour and finish. This is, of course, an important consideration for the manufacturer who has not to bother about spraying. The moulded plastic piece is ready for assembly.
3. Ease of cleaning. The user appreciates the convenience of this, as dirt is easier to wash off a plastic surface than a painted metal one.

Practically the only disadvantage is the inflammability of celluloid and the liability of both celluloid and acetate, particularly the latter, to become brittle after being in use for some time ; the length of time is very variable. This deterioration is probably



Ghosted car fabricated of Plexiglas (" acrylic " resin).
Shown at New York World Fair, 1940.

*Facing p.* 123.]

due to the gradual loss of a proportion of plasticiser and could no doubt be remedied by the choice of a less-volatile plasticiser.

Incidentally, a patent taken out by Auto Union in 1938 described a moulded motor-cycle frame for the D.K.W. machine, consisting of two side pressings bolted together to make a frame strongly reminiscent of the Coventry Eagle channel steel frame. As far as the authors are aware, this revolutionary idea was never exploited, although if a high-impact strength material were used, such as Prestoff, suitably metal reinforced, it might have proved a practical proposition.

**Acrylic Resin Sheet for Windscreens.**

Acrylic resin, particularly Perspex, has been used successfully for the windscreens of a few specially built luxury cars. An experimental design developed by Ranalah Ltd., in 1936, made use of a curved shape and eliminated the sight obstructing and unsightly pillars. The edges of the slightly bowed sheet was sharply curved to provide stiffness and to meet the glass windows with an overlapping weather-proof joint. The screen was recessed into the roof and scuttle at the top and bottom and fastened down with screws. Acrylic resin has also been used for ghosting purposes and a car with a Plexiglas body was displayed by General Motors at the New York Fair. Briggs Motor Bodies also showed one of their productions at the Fair, which was equipped with a roof fabricated of Plexiglas sheet. Probably one of the most complicated and ingenious examples of acrylic resin ghostings ever shown was the transparent Plexiglas casing for a motor engine exhibited at the 1937 German Motor show.

Safety-glass is more economical and generally serviceable for windscreens and windows than acrylic resin, although the latter certainly has the great advantage of being readily mouldable or formed so that curves are possible and improved streamlining is effected. On the other hand, safety-glass has a harder and therefore better-wearing surface and is splinter proof. Acrylic resin, whilst being exceptionally strong, will not prove as satisfactory on impact as a good-quality safety-glass. The real advantage of both acrylic and acetate materials for hoods and screens in aircraft is that they are obtainable in easily formed curves and shapes impossible to secure in glass. Incidentally, of course, weight is of tremendous importance in aircraft production.

It has been suggested that acrylic resin sheet could be used to great advantage for the sunshine roof and there is no doubt that if the price were economic it would certainly prove a constructional material of considerable promise. It is useful, therefore, to consider quite briefly its respective advantages and disadvantages for this application.

*Advantages.*

1. Lightness in weight. Perspex has a specific gravity of 1·19 and is the lightest of all plastics. A wind-screen made of this sheet would weigh less than half that of glass, which has a specific gravity of 2·5 upwards.
2. Excellent light-transmitting properties, as Perspex is substantially better than even the finest quality optical glass.
3. Good mechanical properties, including a very satisfactory impact strength. The fabricated sheet does not shatter when exposed to vibration and sudden shock.
4. Ease of fabrication.

*Disadvantages.*

1. High cost.
2. Comparative softness and therefore easy scratched surface. This necessitates frequent polishing. (Hardening treatment can, however, modify the hardness of the surface and render it more generally serviceable.)

**Safety-Glass.**

Cellulose acetate and vinyl acetate now find very important outlets in the manufacture of safety-glass, where they are used as an interlayer between the two sheets of glass. The plastics chosen for this purpose have to possess a high degree of clarity and a relatively high percentage of plasticiser. According to J. M. DeBell and J. Dahle of the Fibeloid Corporation, writing in *Modern Plastics*, January, 1938, " acetate plastic is furnished in rolls of 0·025 in. thickness, up to 50 in. width and over half a mile in length." The standard method of manufacture, according to these authors, consists of :

first meshing the glass, cutting the plastic to shape, applying adhesive to the glass, assembling the three major elements—two glass sheets and the plastic sheet, prepressing lightly to prevent slippage of glass from the plastic and autoclave under diethylene glycol or petroleum oils at 250 to 300° F. and approximately 150 lb. per sq. in. pressure.

The latest development in the search for an ideal interlayer is the use of polyvinyl acetals, which are said to be more permanent than the cellulose ester, give a tougher and more tenacious film and superior service under difficult conditions. It is claimed that a layer of vinyl acetal resin 0·015 in. thick is equivalent to an acetate sheet of 0·025 in. and, unlike the acetate safety-glass, the new type does not require sealing.

**Lamps and Various Accessories.**

In America lamp cases or shells have been moulded of cellulose acetate reinforced with metal die castings at the base so as to enable them to be screwed on to mudguards. The advantages which can be claimed for these mouldings are, of course, lightness in weight, increased attractiveness coupled with permanent coloured surface and elimination of rattle and noise. Cellulose acetate is more suitable for this application than either phenolic or urea resin, as, in spite of its lower rigidity, it is tougher and better able to withstand vibration and shock than the thermo-setting resins. In addition, it is available in a far wider range of colours and has a better finished surface. These are the considerations which favour the choice of acetate for this purpose.

An interesting development in this country had been a lamp cover moulded of polystyrol resin and designed so that the exterior surface is made up of a number of lenses or small bosses which are able to improve the light transmitting properties of the lamp. Although polystyrol is excellent for this purpose, it has the disadvantage of being somewhat brittle and acrylic resin would appear to be a better choice on account of its greater resilience, higher impact strength and improved light-transmitting properties. Moulded Diakon road signs have proved extremely efficient in those few places where local authorities have been able to pay the relatively high price demanded, but here, of course, the moulded surface merely acts as a reflector and not a transmitter of light.

Various small moulded accessories are now fitted to most modern cars and these include indicators, housings for windscreen

wipers, escutcheons and emblems of various kinds. Standard wood-filled phenolic resins are preferred for the first two applications and cellulose acetate or urea resin for the last two. An interesting innovation is the moulded number-plate, or rather the moulded letters and numbers which slide into a pressed steel case, provided with a glass or transparent plastic cover, to form the complete number plate. The units making up the car number are either pressed out of thin acetate sheeting to form three dimensional letters and numbers or merely cut out of the sheet and stuck down flat with cement on to a panel of white or black acetate so as to stand out in immediate contrast. White letters and numbers on a black base are usually preferred. Either toughened glass, clear acetate or acrylic resin is used for covering the fitting, which is, of course, illuminated from the base. A number of sports cars, such as the M.G., are fitted with this kind of number plate, which is both smart and serviceable.

**Synthetic Rubber in the Motor Industry.**

As mentioned in a previous chapter, there are a number of different kinds of synthetic rubber, the best known being neoprene, Thiokol, Buna and Gaco. All these vary somewhat in characteristics and workability, but they all share a remarkable resistance to lubricating oils and petroleum, as well as heat, ozone, abrasion and a wide range of chemicals.

Synthetic rubber is an obvious material for the motor-car manufacturer and can be used to advantage for every rubber application, except tyres, in the modern car. The only obstacle to its general adoption for applications involving exposure to heat, contact with oils, oxygen and ozone, etc., is its price, this being in the region of four times the price of natural rubber. It is, however, possible to reduce this price quite considerably by using a mixture of synthetic and natural rubber, utilising special synthetic rubber compositions, such as gaskets made of paper impregnated with Thiokol and other cements, etc.

British manufacturers are not as yet (1940) making the same generous use of synthetic rubber as those in the United States, where for the last five years, at least, America's big three have been exploiting its unique properties. One of the most important American applications is the use of synthetic rubber tubing for conveying the motor spirit to the carburettor. In this country

applications are generally confined to various kinds of gaskets and washers, many of which are required for the modern car. It is, however, interesting to note that the new Girling hydraulic brake system makes use of neoprene tubing, which is quite unaffected by the hot oil pumped through the hose.

Probably the most important use of synthetic rubber in the motor field is for the lined pump hose and tubing used by filling stations. In spite of the very considerable difference in price between natural and synthetic rubber, it has been found economic to use the latter in view of its much longer life and greater serviceability.

| Material. | Method of Fabrication. | Present Uses in Motor-Car Construction. | Possible Future Uses |
|---|---|---|---|
| Phenol-formaldehyde resin | Compression moulding | Facia boards. Window fillets. Windscreen pillars. Knobs. Controls. Indicators. Ash-trays. Large moulded units, such as doors (Auto Union). Housings for windscreen wipers. Distributor caps | Bodies. Pistons. Gear change covers. Air cleaners and silencers. Frames of motor-cycles. Ventilators. Carburettor bodies. Oil pumps |
| Laminated sheet | Formed from uncured sheet or fabricated from fully cured sheet | Timing gears | Backs of front seats. Fans. Sunshine roofs (sliding panel). Parts of car bodies |
| Cast resin | Cast or fabricated from rod, tube or sheet | Facia boards. Gear knobs and controls. Mascots. Escutcheons | |
| Urea-formaldehyde resin | Compression moulded | Lamp lenses or covers. Gear knobs. Controls. Shades for interior lights | |
| Cellulose acetate<br>Cellulose acetate butyrate | Injection or compression moulded, usually the former<br>Injection<br>Extrusion | Parts of facia boards. Steering-wheel covers. Glove compartment doors. Safety-glass interlayers. Wheel hub-caps. Mudguards for motor-cycles. Ghosting cars for show purposes. Grease guns (Tecalemit). Number plates. Window handles. Controls. Gear knobs. Horn buttons. Lamp shells or bodies. Extruded strips for interior trim | General extension of present applications, particularly in combination with metal parts |
| Acrylic resin | Formed from the sheet, such as Perspex, or compression moulded from the powder | Windscreens. Mascots. Road signs. Signals. Lenses for rear direction. Ghosting cars for show purposes | Sliding panel of sunshine roof |
| Polystyrol | Injection and compression moulded | Lenses for lamps | Distributor caps |
| Vinyl | Used as a thin sheet for the interlayer of safety-glass | Safety glass interlayer. Petrol hose (Koroseal and Mipolam). Cable sheathing (German cars) | |
| Synthetic rubber | Cut from sheet and moulded from sheet and powder | Cable sheathing. Petrol hose. Tubing for Girling brakes with hydraulic operation. Caps used in wheel cylinders. Gaskets | Recommended for all rubber applications (except tyres) in the car mechanism where high resistance to oil, petrol, heat and ozone are required. |

## CHAPTER IX

# TEXTILE INDUSTRY

It is not our intention to describe in detail the production of textile fibres, such as viscose, cellulose acetate, nylon, textile-casein or Lanital and the new vinyon yarn, but rather to give brief summaries of the principal stages of manufacture which, it is hoped, will be of some guidance to non-textile readers.

Great progress has been made in the development of synthetic fibres, but there is still plenty of room for improvement, particularly as regards increased elasticity, reduction of swelling on wetting and the conferring of the property of felting inherent in the scale structure of wool. These are mentioned by Mr. B. H. Wilson, Director of the Wool Industries Research Station, in an article on " Competitors of Wool " contributed to the Trade and Engineering Supplement of *The Times*, October, 1939. He also stresses the fact that man-made fibres are essentially " cold " and attributes this not only to low thermal conductivity, but to the lack of heat generated in a fibre when it absorbs water. Mr. Wilson explains this as follows : " When we put on an overcoat and go from a heated room into cold outside air, there will be a corresponding increase in the relative humidity, so that the fabric will tend to take up water." Fibres such as acetate and nylon, which show comparatively low differences in absorption at different humidities, are naturally rather chilly fibres. It is highly probable then that chemistry alone will never produce the ideal " warm " textile fibre. This warmth may be connected with the amount of occluded air or, rather, air spaces in the fibre, thus giving increased insulation. Again, the artificial fibre is always smooth, thus producing a minimum surface energy for the absorption of moisture and formation of exothermic energy.

It is interesting to recall the prophecy made some years ago by Standinger, who said that the most successful synthetic fibres of the future would approach the animal silks and wool in chemi-

cal constitution. Both Lanital and nylon do this and are, in fact, the only man-made protein fibres in existence. The authors are, however, of the opinion that the future of synthetic fibres is bound up as much, if not more, in the physical formation of the fibre, rather than the chemical constitution.

## TEXTILE FIBRES

### Collodion or Chardonnet Silk.

This is the earliest artificial silk or rayon, but it is still being manufactured in France and enjoys a fairly steady sale, in spite of the encroaches of other cheaper types of rayon. Cotton or cotton linters is the raw material employed and this is nitrated with a mixture of sulphuric and nitric acids. The acid is then removed by pressing or centrifugal action and the nitro-cellulose washed, bleached, and finally washed and vacuum dried. The cotton-like material formed as a result of this process is dissolved in certain solvents, usually a mixture of alcohol and ether, and the solution spun by the wet or dry process. The nitro-cotton filament is denitrated by passing it through sulphide baths.

### Cuprammonium Silk.

Moist wood pulp or cotton linters are dissolved in " Schweizer's Solution," made by adding copper hydroxide to ammonia. The cuprammonium solution is then spun by the " stretch spinning " process and the fibre treated with weak hydrochloric acid to remove all traces of copper. It is well washed, so as to leave the rayon free from all traces of acid.

### Viscose.

Two English chemists, C. F. Cross and E. J. Bevan, patented viscose in 1892 and so founded what is now a world-wide industry. Wood-pulp is the starting-off point in the production of viscose. This is converted into alkali cellulose by the action of caustic alkali and the mass then crumbled or torn into small fragments. After maturing for a short time, carbon bisulphide is added, which dissolves the alkali cellulose to form an orange-coloured viscous compound, cellulose xanthate. Caustic soda solution is added to this and the thick viscose allowed to ripen for a day or so, during which time the viscosity drops considerably. The next operation

is spinning, which is carried out by the wet process in a bath of sulphuric acid and sodium sulphate. The fibres are washed, dried and later passed through a number of chemical baths destined to improve the strength, texture and appearance of the fibre.

**Cellulose Acetate.**

The raw material is cotton linters, that is, pure cellulose. This arrives at the plant in large bales, which are opened out and the linters pre-treated ready for acetylation. This takes place through the action of acetic acid, acetic anhydride, a suitable solvent, such as methylene chloride and a catalyst. When the chemical action is complete, the mass is hydrolysed by the addition of water and the precipitated cellulose acetate removed, washed, drained and dried. The granular white material produced by this chemical action is dissolved in acetone, plasticised, extruded through orifices and the filaments spun.

It is not suggested that the above very brief account gives a true picture of the complexity of the manufacture of rayon, but it should at least help the non-technical reader to differentiate between acetate and viscose.

**Textile Casein (Lanital).**

This protein fibre has been greatly improved during the last two years and it is now claimed to be 85 per cent. as strong as natural wool. Its development is due mainly to the totalitarian policy of Fascist Italy, which fosters all industrial processes calculated to make that country independent of foreign supplies, in this case wool. Although one can admire the enthusiasm of this self-sufficiency campaign, it is not possible to disregard the fact that Italy normally imports casein from Holland and Denmark to make Italian "wool." In a grave national emergency it is doubtful whether Lanital could be manufactured on a large enough scale, because, under such conditions, casein is not likely to be available in Italy in the large quantities required for the proper development of the new fibre.

Lanital and similar casein textile fibres are produced by dissolving casein in a dilute solution of an alkali, such as caustic soda, extruding the viscous compound in the form of fine filaments coagulating in an acid bath and then rendering them insoluble by treatment with formaldehyde. Stripped of all technicalities, this

process certainly does appear to be a simple and economical one, but workers have found it to be by no means as simple and foolproof as it might at first appear to be. Indeed, the early results produced very poor quality fibre, only 5–10 per cent. as strong as natural wool.

The modern greatly improved casein fibre is due mainly to the work of Dr. Antonio Ferretti, who spent some years carrying out research work and later sold his patents to Snia Viscosa. According to Sutermeister and Browne, *Casein and its Industrial Applications*, the Italian process utilises a dispersion of casein in aqueous alkaline solution, to which is added some such agent as carbon disulphide. The solution is then extruded, coagulated in sulphuric acid and, after drying, treated with formaldehyde. These authors repeat the assertion of the Italian rayon company that 1 lb. of casein yields 1 lb. of Lanital. It can apparently be cut to any staple, 4½ in. being the average, as compared with 6 in. to 7 in. for wool, and the fibres can be spun to the finest counts.

Modern Lanital is claimed by some experts to have certain advantages over wool, the most important being:

1. More uniform structure, that is, shows no tip and root effect, possesses more uniform contour and better lustre.
2. Requires no scouring or carbonising.
3. High affinity for dyes.

Lanital and wool are in many ways similar and it is claimed that the spinning of finer grades of Lanital is greatly facilitated by blending with wool. There is no doubt, of course, that a percentage of natural wool is essential in the making up of the synthetic product and very little Lanital is used alone.

Main disadvantages of the new textile are immediate loss of strength on wetting, poor elasticity and susceptibility to bacterial and fungoid attack. However, it is probable that most of these drawbacks will be overcome and it has been suggested that a possible line of development lies in its mixture with viscose. It is of interest to note that a fairly recent British patent, No. 501,531, describes the manufacture of wool-like fibres from viscose solutions containing protein. In an example given, viscose is produced from alkali cellulose and 7·5 litres of it, containing 7·5 per

cent. cellulose and 6·5 per cent. alkali, are mixed at reduced temperature with a solution of 300 grm. of fresh casein. Immediate spinning of this solution is then effected through 0·08 mm. diameter nozzles in gold-platinum, into a bath of 80 per cent. methanol and 20 per cent. water.

**Nylon.**

The most interesting textile material is nylon, a product of the du Pont Company, because it is the only really true synthetic fibre in existence, all other materials, such as acetate and casein, being produced by the chemical treatment of natural compounds ; cellulose in the case of rayon and the protein casein in the case of Lanital. Nylon is particularly interesting because, although it is at present almost exclusively employed as a textile fibre, it has, like cellulose acetate, great promise as a plastic material. It can be both extruded and moulded, although relatively high temperatures have to be used, i.e. in the region of 234° C. On a price basis, nylon is a good deal more expensive than rayon and even approaches that of pure silk. It should, however, be realised that the specific gravity of the synthetic protein fibre is only 1·14, whereas acetate varies from 1·27 to 1·60. The low specific gravity of nylon is sure to be a factor of very great importance in the future, especially when the material enters the legitimate plastics industry.

Nylon is a fibre made from a material which is probably the nearest man has approached to the proteins of the body. To understand its manufacture we must go back to the wonderful work of Emil Fischer, who, over fifty years ago, broke down the very complex animal proteins into, first, the polypeptides, in themselves very complicated molecules and, finally, into the simple amino acids of small dimensions. Emil Fischer also worked the reverse way and from simple amino acids reconstructed complicated polypeptides, but never reached the final protein matter. Du Pont have carried on this work on a manufacturing scale and, going further than Fischer, have produced fibres closely resembling those formed in the animal kingdom.

Clues to the synthesis of nylon are given in two patents, E.P. 461,236 and E.P. 461,237. The first deals with the condensation products formed when certain monoaminocarboxylic acids are heated in the presence of an inert diluent, such as xylenols and

cresols, etc. The viscous product finally formed by melting the protein is extruded under pressure. The second or later patent claims to produce a substance with improved extruding properties. Here the viscous nylon is prepared by heating under pressure a mixture of certain diamines and carboxylic acids in the presence of an inert diluent. The diamines are typified in the patent as those chiefly containing polymethylene groups, e.g. tetra, penta, hexa, deca, octadecamethylene-diamines and the acids by glutaric, adipic, sebacic, etc. Apparently when a mixture of a suitable acid, such as sebacic acid produced from castor oil by oxidation with caustic alkali and a diamine, e.g. pentamethylene-diamine, are heated together in the presence of a solvent and under undisclosed chemical conditions, condensation first takes place, promoted by an acid or acyl chloride, etc., and the product formed is polymerised to form a viscous substance, which can later be precipitated by adding alcohol and filtering. The residue is then melted by heating to 234° C. and forced under 3 lb. nitrogen pressure through tiny orifices 0·47 mm. diameter and the extruded filaments wound on an electrically driven drum.

Theoretically it would seem that protein-like compounds of the type of nylon could be produced from petroleum, the long chain hydrocarbons being oxidised to form dibasic acids of the sebacic-acid type which could be reacted with diamines. This is yet another way in which petroleum offers great possibilities for future development in the realm of plastics.

Nylon has a density of 1·14 and a tensile strength of 5 grm. per den. dry and 4·4 grm. per den. wet.

Elongation dry about 20 per cent.
,, wet ,, 30 per cent.
Loop strength dry 95 per cent. of tensile strength.
Elastic recovery—against no load.

| *Per cent. Stretch.* | *Per cent. Elastic Recovery.* | *Per cent. Stretch.* | *Per cent. Elastic Recovery* |
|---|---|---|---|
| 2 | 100 | 8 | 100 |
| 4 | 100 | 16 | 91 |

Stretch held 100 sec., recovery in 60 sec.

Modulus of elasticity, resistance to stretch. To stretch 1 per cent. requires 0·5 g. per den.

Calculated modulus of elasticity—505 kg. per mm.$^2$ or $7 \cdot 25 \times 10^5$ lb. per sq. in. Stress strain approx. linear up to 4 per cent. stretch.

Moisture regain—total absorbed averages 7·5–8·0 per cent.

Chemical resistance—bleaching agents. At room temperature hydrogen peroxide and sodium hypochlorite in 3 per cent. concentration for two hours or 0·2 per cent. for sixteen hours do not affect tenacity. Inert to acetic acid 20 per cent. 25° C.

(These figures are reproduced from *Amer. Dyestuff Reporter*, 1939.)

**Comparison of Synthetic Fibres.**

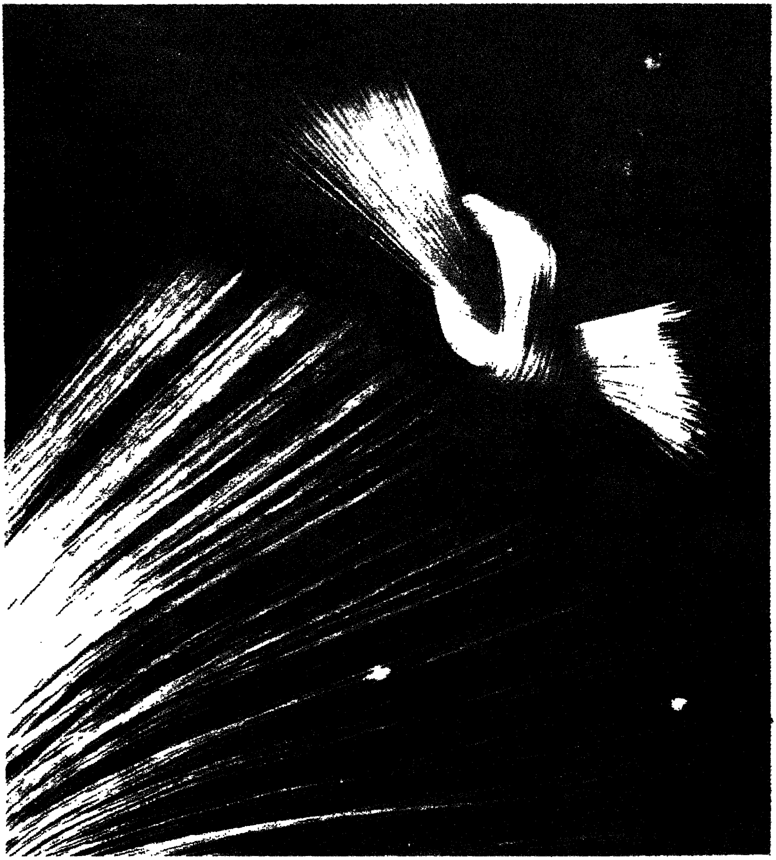
Nylon is easily the strongest of all synthetic textile fibres, being over twice as strong as acetate, four times as strong as casein and a fifth again as strong as the best viscose. Probably the most outstanding difference between nylon and the other synthetic fibres lies in a comparison of their tensile strengths in the dry and wet conditions. There is very little difference in the figures for nylon, amounting to only 6 per cent., whereas the best figures for viscose show a difference of 35 per cent. between the wet and dry tensile strengths, acetate being 30 per cent. and casein fibre 46 per cent. Differences between maximum stretch in wet and dry conditions for the various fibres is also of interest. Nylon alone possesses a greater degree of stretch in the dry condition than in the wet, the actual difference being 3 per cent. greater in the dry state. Viscose is 17 per cent. greater in the wet condition, acetate 2 per cent. and casein too variable to be of value.

The figures on the following page are given by Mr. B. H. Wilson, Director of the Wool Industries Research Station (Trade and Engineering Supplement, *The Times*, October, 1939).

The new vinyon fibre now being manufactured by American Viscose Co. under licence from the Union Carbide Chemical Co., U.S.A., has a tensile strength ranging from 1·0 to 4·0 grm. per denier, whereas nylon is 5·0 grm. per denier. Tensile strength, when wet, is substantially the same as when dry and therefore closely resembles nylon. The vinyon fibre is non-inflammable and highly resistant to chemical attack and at temperatures up to 150° F. it is unaffected by mineral acids and alkalis, except in high concentration.

In Japan and, to some extent, in the Ford-sponsored soya-bean

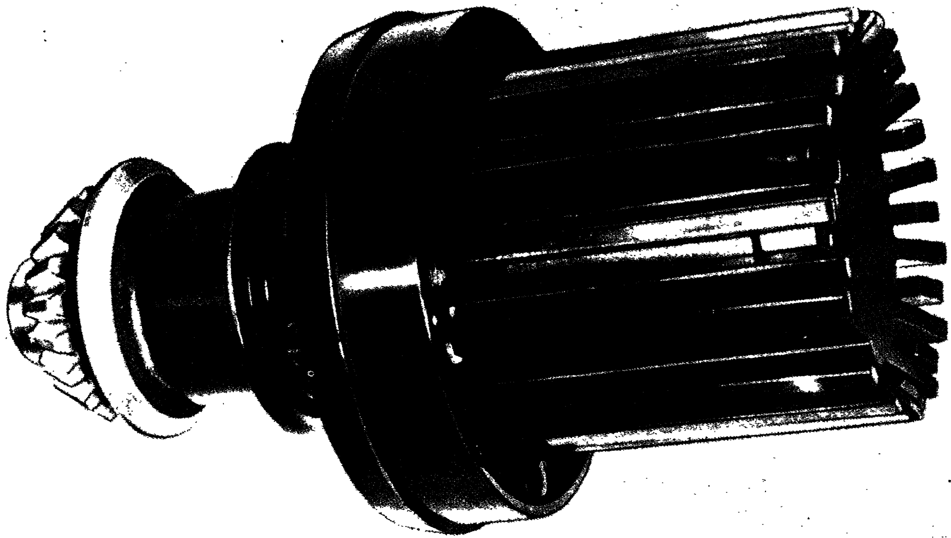
| Property. | Condition. | Wool. Min. | Wool. Max. | Silk. Min. | Silk. Max. | Cotton. Min. | Cotton. Max. | Viscose. Min. | Viscose. Max. | Acetate. Min. | Acetate. Max. | Casein. Min. | Casein. Max. | Synthetic Fibre Nylon. Min. | Synthetic Fibre Nylon. Max. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Tensile strength: Kg. per sq. mm. | Dry | 13·5 | 21·6 | 46 | 70 | 21 | 80 | 18 | 40 | 16 | 21 | 10 | 12 | 51 | — |
| " " " " | Wet | 11·5 | 16·6 | 47 | 52 | 24 | 83 | 8·6 | 20 | 10 | 12 | 5·2 | 5·6 | 48 | — |
| Per cent. | Wet/Dry | 79 | 97 | 86 | 95 | 99 | 113 | 42 | 65 | 59 | 70 | 43 | 54 | 94 | — |
| Maximum stretch: Per cent. | Dry | 28 | 74 | 7 | 25 | 5·7 | 12·5 | 7·8 | 26 | 21 | 30 | Variable | | 26 | 60 |
| " " | Wet | 35 | 80 | 24 | 36 | 6·1 | 13·2 | 9 | 43 | 26 | 32 | 83 | 110 | 30 | 57 |
| Modulus of elasticity: Kg. per sq. mm. | Dry | 260–400 | | 700 | | 600 at 65% R.H. | | 700 | | 500 | | Plastic | | 505 | |
| Hooke's law range: Per cent. (stretch) | Dry | 5 | | 3 | | 3 | | 1 | | 1 | | | | 4 | |
| Extension: Per cent. length | Dry | 28 | 74 | 10 | 14 | 6 | 10 | Practically none | | Max. 5% | | No recovery | | 16 | 100 |
| Recovery: Per cent. extension | Dry | 100 | 80 | 53 | 45 | 40 | 30 | | | | | | | 91 | 24 |
| Regain | 30% R.H. | 8·8 | | 6·5 | | 4·0 | | 8·0 | | 3·0 | | 16·3 | | 2·0 | |
| Grm. of $H_2O$ per 100 grm. wool | 80% R.H. | 19·0 | | 17·4 | | 10·2 | | 18·0 | | 9·0 | | 20·4 | | 5·5 | |
| Difference | — | 10·2 | | 10·9 | | 6·2 | | 10·0 | | 6·0 | | 4·1 | | 3·5 | |



Nylon, the new synthetic fibre used for making bristles, etc.

(*Courtesy : Imperial Chemical Industries Ltd.*)

[*Facing p.* 136.



Moulded thread-advancing reel developed by Rayon Machinery Corporation, Ohio.
Moulded of Durez phenolic resin.

Facing p. 137.]

works, synthetic wool-like fibres are being spun from solutions of soya-bean proteins and also other proteins of marine and animal origin. I. Sakurada (*J. Soc. Chem. Ind. Japan*, 1939, **42**, 191–2B) states that the strengths and load-extension diagrams of these fibres are similar to those of casein fibres, but the fibres are weaker than those of viscose and less extensible than natural wool. The ratios of wet to dry strengths for synthetic protein fibres, viscose and merino wool are, respectively, 31–37, 48 and 75 per cent.

**Vinyon Fibre.**

At the time of writing very little is known about the manufacture of this new vinyl fibre, but apparently it is a derivative of polyvinyl acetate. It is stated to be closely related to vinylite, which is produced by condensing polyvinyl alcohol with butyraldehyde. According to *Chem. and Met. Engineering*, No. 11, November, 1939, vinyon yarn is available in staple fibre and continuous filament, the latter in practically all deniers. It is a multi-filament yarn with a filament denier even finer than silk. The yarn can be produced at will with a tensile strength in the range of 1·0 to 4·0 grm. per denier. Wet or dry, its tensile strength remains substantially the same. Chemically the new yarn is relatively inert and has a strong resistance to chemical attack. For this reason one of the chief uses of vinyon is for filter cloths to be used in the chemical industry. The fibre is dissolved by the lower ketones and certain halogenated hydrocarbons ; it is swelled by ethers, esters and aromatic hydrocarbons, glycols or aliphatic hydrocarbons. The elasticity of the fibre is very similar to that of silk. Vinyon is a true thermoplastic, a temperature of approximately 165° F. being about the maximum that can be used without damage to the yarn. The " set " yarn, the type normally produced, is stable with respect to shrinkage up to the temperature of the set—usually 150° F. Above the set temperature shrinkage occurs, which is accompanied by a slight reduction in tensile strength and a corresponding increase in elongation. It appears that this new fibre has its chief applications in the realms of industry where there is a growing need for high chemically resistant fabrics. Of interest also is the new fibre " Vistanex " which is an isobutylene fibre produced by dissolving isobutylene in hexane and forcing solution through a spinneret.

**Use of Resins as Textile Finishes.**

The technologist in the textile industry appears to be turning more and more to synthetic resins as replacement materials for the usual starches and softeners employed in the finishing of cotton piece goods. The claims made for the resins are that they are more permanent, that is, they withstand laundering and dry cleaning, they do not affect the tensile strength of the fabric, indeed, they sometimes improve it, and their use enables the finisher to obtain results not possible by any other means.

Probably the best-known use of textile resins is the anti-crease process originated some years ago by Tootal Broadhurst Lee Co. Ltd. This makes use of a water soluble urea-formaldehyde resin which is converted into an insoluble form by subjecting the treated textile to relatively high temperatures, i.e. in excess of 250° F. Urea-formaldehyde resins, either in the water soluble or polymerised form, are also employed for glazed fabrics, the glaze being permanent and able to withstand the action of laundering and dry cleaning, whereas, of course, starched goods lose their original good looks after washing and have to be re-starched and glazed. It is likely that urea-formaldehyde resins will be usurped from their present ascendant position by the acrylic and methacrylic acid which are recommended for practically the same purposes. A recent patent taken out by Rohm and Haas Akt-Ges, E.P. 467,598, mentions the use of aqueous dispersions of polymerised acrylic or methacrylic acid containing glue. The sizings are fast to washing and dyeing and need not be removed. The sized threads do not stick and a close warp may be woven satisfactorily. The size mentioned in the patent makes use of 25 per cent. aqueous dispersion of a methyl ester or polyacrylic acid ; 56 parts of this are mixed with 6 parts of glue and 38 parts of water ; 100–150 grm. per litre of this mixture is used for warp sizing. Alkyd resin emulsions are being utilised in special slip-proofing solutions for rayon.

Some of the latest textile resins are modified by the addition of starch and the new Hercules semi-resin (Textac) is a good example of this type. It is claimed that the following advantages are obtained by adding this material to a starch or softener :

1. Superior body and fullness.
2. Brighter colours caused by the increased translucency of the mix.

3. Better toughness and flexibility.
4. Increased uniformity of the finish from selvedge to selvedge.
5. Better stability of the finish.

An interesting application of synthetic resins is now being found in their use as a thickener for printing colours. Dr. Hans Gerber, *Melliand*, describes the use of mixed polymerisation products of polyacrylic acid for this purpose. Phenolic resins are also being used in place of shellac for stiffening bowler hats.

Plastics are also being fairly extensively employed as a bonding material for laminated fabric. In *Textile Weekly*, February 2, 1940, reference is made to the plastics used for this purpose. These include polymerised solutions of vinyl acetate and chloride, co-polymers of methyl methacrylate and vinyl chloride and also polystyrene. A coating solution for the cotton inter-liner makes use of a solution consisting of 8·5 parts polystyrene, 1·5 parts diethyl phthalate, 85 parts benzene and 5 parts xylene (E.P. 473,478). Chlorinated rubber is used either alone or as a modifying agent for synthetic resins, also synthetic rubber and rubber-like plastics, such as polyisobutylenes derived from petroleum. Cellulose esters used for laminated fabrics include cellulose acetate, cellulose acetopropionate and cellulose acetobutyrate, also ethyl cellulose, which has a high resistance to acids and alkalis, great inherent flexibility and high melting point.

## Resin-like Bodies for Preservation of Textile Fibres.

Some attention has recently been given to the use of synthetic resins for the preservation of textile fibres, wood and other types of cellulose. Although it can be said that practically all water-resistant products, such as synthetic resins, possess useful preservative properties in so far as they prevent bacteria and fungi from attacking the cellulose, in general practice only a few materials are practical. The most promising are the resin-like metallic naphthenates, particularly copper, zinc and iron used in the form of white spirit solutions or as emulsions in water. It is of interest to note that the most satisfactory method of rot-proofing sandbags is by impregnating them with a white spirit solution of copper naphthenate so as to leave the equivalent of 0·5 per cent. metallic copper in the fibres after treatment. Mixtures of copper and

aluminium naphthenates in white spirit are used for rot-proofing fishing nets, and mixtures of the naphthenates with tar are recommended for treating ropes.

Dispersions of acrylic and methacrylic resins may possibly be of value as preservatives if the price could be brought down to an economic level. Other chemicals of likely interest are the chlorinated diphenyls or arochlors, which have a high resistance to moisture, although it is not known whether they possess any disinfectant or fungicidal properties.

## PLASTICS FOR TEXTILE MACHINERY

Almost in spite of the textile industry, plastics are now being employed for many important pieces of plant from gears to special reels in viscose manufacture, friction rollers to picking sticks and dyeing vats to dye sticks. These applications, most of which have been very successful, are mainly due to the initiative of the plastic manufacturer out to find new uses for his materials and only in a few instances can new developments be traced to the collaboration of textile and plastics interests. The general attitude of the textile manufacturer towards plastics, and it must, unfortunately, be admitted that he usually knows very little about these materials, is that first of all they are expensive when compared with wood or metal and, secondly, they are not strong enough for his work. The second disqualification is frequently supported by a remembrance that so and so in Leeds or Bradford once tried out a moulded bobbin or laminated roller, but it cracked or warped, etc. It is useful to consider, if only very briefly, these supposed disadvantages of plastics. Naturally, the question of costs is all important, especially in such a highly competitive and, until the war, depressed industry as textiles, but cost is surely dependent on length of service. If a unit made of wood lasts $x$ weeks and a similar one moulded or fabricated of plastics lasts $5x$, then surely, even if the plastic unit is twice as expensive as the wooden one, it is in the end a good deal cheaper. This is so elementary that we hesitate to stress the point, yet it is a very real one. The great value of the properly designed plastic piece of plant depends, to a large degree, on its ability to give a better or longer service than one made of a standard material. Initial expense is not, therefore, the prime factor; indeed, it may mislead the manufacturer and

turn him from supposed extravagance to false economy. As regards strength, plastic materials are available or they can be developed to satisfy most requirements ; it is usually merely a question of co-operation and real collaboration. If the plastic material manufacturer and the moulder or fabricator know for what purpose the part is required and the conditions of service it is expected to stand up to, then they can at once advise the prospective customer whether the particular application is a suitable one. Plastics are the most adaptable materials in the world and it is a great pity that this fact is not better known than it deserves. Whilst, say, a standard grade of phenolic resin may not prove suitable for a certain purpose, this does not mean that all phenolic resins are unsuitable. By altering the filler and rendering the finished moulding better able to withstand heavy impact strength, or perhaps able to resist heat and chemical action to a greater degree, the correct material could be found and satisfaction ensured.

It is not possible to catalogue every individual application of plastics in the textile factory, but it is hoped that the following applications will not only indicate the lines along which developments have already taken place, but suggest new uses for the future.

**Moulded Reels for New Viscose Process.**

One of the most interesting and probably the most important moulded unit in the textile industry is the plastic thread-advancing reel developed by Rayon Machinery Corporation, Cleveland, Ohio, U.S.A., and moulded of Durez phenolic resin. More than 86,000 of these reels are now in regular use at the Corporation's new plant in Painesville, Ohio, and they enable considerable economies to be made in processing ; indeed, their development has assured the success of the new continuous process of the Rayon Machinery Corporation.

To understand fully the function of the moulded reel it is as well to consider briefly the process in which it is used. According to General Plastics, Inc., manufacturers of Durez, in the old process of viscose manufacture the yarn was drawn from the bath of acid directly on to a spool or in the centrifugal process it was drawn by a glass wheel or godet and then passed through a rapidly rotating bucket and thence through many washings and other

operations requiring much handling. Further, the yarn on the outside of a package or a spool received a very different treatment from the yarn not on the outside: or if handled in skeins, it required repeated re-handling.

The process used in the Rayon Machinery Corporation's new equipment avoids all this by conveying the threads through the spinning, treating, washing and drying without putting the yarn into a package until it has passed to a cap twister and wound on to a bobbin as completely processed yarn, the bobbins being removed when full without stopping the machine.

These moulded reels are not affected by the treating solutions or by water. The treatment is effected by passing the yarn from reel to reel, by showering the reel and the yarn passing over it with the proper treating liquids or wash water. Since the yarn does not wrap on itself and form layers when traversing the reel, but passes forward constantly, treating liquids reach the thread directly and not through layers of the package and the uniformity of the treatment is obvious.

Each reel assembly includes two overhung slat pulleys, flanged hub and bolts, flexible diaphragm seal, laminated seal clamp washer and macerated bevel gear. Yarn fed on at the back of the reel advances in a series of evenly spaced helical wraps as the reel is rotated and drops from its outer end to the next reel in the stepped vertical sequence embracing nine spinning and processing operations. The spacing of the yarn on the reel has been worked out carefully to provide proper treatment time at each stage and to allow various processing liquors to cover the turns on the rotating advancing layer of yarn.

The development of this reel represents the culmination of six years of research, not only directed towards what might be called the mechanical side or designing, but concerned with the production of a special grade of resin able to withstand the very severe conditions of service. It speaks well for the teamwork put in by the technicians of the Rayon Machinery Corporation and General Plastics, Inc., that their joint efforts are now crowned with success. The authors are of the opinion that it is only by such co-operative efforts that outstanding contributions will be made by plastics to modern industry.

**Moulded Bobbins and Pirns.**

A large number of these moulded of standard phenol-formaldehyde resin powder are now in use in place of wood. Although more expensive than the latter, a factor of the greatest importance to the mill, they offer important advantages. In the first place they are claimed to be much stronger than wooden ones and thus their use eliminates a large percentage of breakdowns and waste of yarn. In the second, it is stated that the finish of the moulded bobbin is superior to that of the best wooden bobbin and, in consequence, the yarn is not likely to catch or tear. This means greater efficiency and increased production. At least one well-known moulder is now producing moulded bobbins in a range of colours for the convenience of managements who wish to make use of a "Colour Code." It is interesting to find that a large percentage of moulded bobbins are used in flax and jute mills where they have to stand up to more strenuous working conditions than the moulded pirns used in cotton mills. Apparently those firms who have made use of mouldings for this purpose are well satisfied with the results, but the proportion of moulded bobbins compared with wooden ones is still very small, owing, primarily, to the fact that the latter are a good deal cheaper to purchase.

**Laminated Material finds Important Applications.**

Whilst mouldings are well fitted for many applications involving the use of several thousand units, such as the reel in viscose manufacture and the bobbin, there are many processes where plastics could usefully be employed but where large numbers of moulded parts are not required. This is where laminated material is particularly useful, being specially suitable for series production, as opposed to mass production.

Laminated sheet, rod and tube can usually be obtained in dimensions suitable for fabricating by the textile engineer or it may be purchased in fabricated form direct from some material manufacturers. The advantages which can be claimed for laminated material, the laminæ being either paper or fabric, usually the former, can be briefly summarised :

1. High mechanical and dielectric strength.
2. Maximum resistance to chemical action.

3. Non-staining.
4. Smooth surface which also wears smooth.
5. Low weight as compared with metal.
6. Excellent machining qualities.

The most interesting applications so far found for laminated material include temple rollers, guide rollers, loom gears, tenter rails, etc. In the case of tenter rails, an American application, the use of plastics instead of maple woods has rendered possible an increase in the speed and efficiency of the process as wood, even the finest and best-seasoned grades, cannot withstand the severe conditions of tentering without warping. It is claimed that the use of laminated material for this purpose increases the life at least tenfold.

**Plastics for the Dyer and Finisher.**

It is surprising that greater use is not made of plastics for dyeing and finishing plant, as they are very suitable for the purpose and their use often enables worthwhile economies to be made. The authors understand that Keebush, the cold moulded phenolic resin, has been used to some extent for making dye-vats and it is remarkably resistant to the action of acids at temperatures up to 130° C. It is not, however, suitable for use where alkaline solutions have to be employed. Although plant made of material such as Keebush or Haveg is naturally expensive, it is not as costly as when fabricated of stainless steel or Monel metal and will give a comparable length of service. For specialised plant to be used in the Drisol process involving the use of sulphuryl chloride, Keebush should be particularly useful. The German cast resin, Dekorit F., is said to be used for acid-resistant plant and appears to be suitable for certain types of dyeing vats and pipe lines. This new plastic does not warp, shrink or swell in the presence of moisture or when subjected to wide changes in temperature and is stable up to 130° F. It is resistant to all oils and chemicals, except nitric, and may be used for alkaline solutions. Obviously, the low maximum temperature allowed for solutions limits the application of this cast resin in the textile industry.

The use of protective finishes, such as Lithcote, is also recommended for use where increased acid resistance is required. This coating can, of course, only be given to metal plants and is no

use for ordinary wooden paddles and vats. Like Haveg, Lithcote is not suitable where processes involve treatment with alkaline solutions.

The authors are of the opinion that use could be made of laminated sheet for simply designed pieces of plant. Vats would require reinforcing in some way to give the necessary rigidity and robustness, but this need not be a serious obstacle. Paddle blades in particular might easily be built of laminated sheet, which would stand up to hard wear a good deal better than wood, which soon gets worn and is liable to tear delicate goods. Rods and tubes of laminated material (paper-filled) are now in use as dye-sticks and are unaffected by immersion in dyes.

Apart from the use of what might be called the legitimate plastics for textile processing vessels, it is suggested that greater use could be made of chlorinated rubber or, indeed, ordinary rubber-lined iron vats, etc. Such vessels have a long life and will protect the metal from the corrosive effects of all acids and bleaches likely to be employed in dyeing and finishing works.

**Impregnated and Compressed Wood.**

This is not at present finding any major applications in this country, but in France the writers understand that picking sticks, shuttles, friction rollers and gears are being made of both standard grades and specially developed varieties. Large industrial fans are also being fabricated of impregnated and compressed wood and it is claimed that these are able to stand up to unusually severe conditions which would impose a severe strain on the more costly light alloys.

There seems to be a great future for impregnated and compressed wood in the textile industries, as it possesses all the physical properties required and, in addition, is easy to fabricate.

## CHAPTER X

# BUILDING INDUSTRY

### Plastics in Modern Building.

Except for obvious applications, such as moulded door furniture, switch covers and the more recent extruded curtain railing, moulded cisterns, etc., plastics are not used to any extent in building practice. The architect has shown a certain amount of interest in plastics, but it must be admitted that his attitude has not always been helpful, mainly because he has made the fundamental mistake of regarding plastics as mere substitutes. In consequence, he has examined them with a hypercritical eye and shown little sympathy for the teething troubles of a very young industry. It is, however, encouraging to find that this attitude of suspicion is slowly but surely giving way to real interest in the possibilities of the new materials and an appreciation of the fact that plastics are essentially new materials with their own individual and often special characteristics.

It is not suggested that plastics can be regarded as general building materials, but they are certainly of considerable interest for specialised applications where ordinary standard materials are not quite suitable. Take, for instance, the field of panelling in restaurants, hospitals, ships, shops, etc. Laminated sheeting offers a wide range of attractive solid colours, also mottles, and properties not possessed to the same degree by natural materials, such as wood, marble, tiles, etc. These properties include not only a good resistance to fire, but heat insulation to a high degree.

It is only by sympathetic co-operation between the architect and the plastics industry that real progress can be made in this important field. There is plenty of scope for plastics in the building industry, but it is of rather a specialised than a general nature.

**Resin Bonded Plywood a New Building Material.**

Considerable progress is now being made in America with resin-bonded plywood, the resin in this case being a liquid phenolic resin specially prepared for bonding wood by Durez Chemicals Incorp., formerly General Plastics Incorp. Not only have a number of private houses been built of resin-bonded plywood, but also several garages and petrol stations. It is claimed that this new form of building sheet is highly resistant to moisture, fungi and insects, resistant also to fire and possesses very flattering physical properties which make certain of its ability to give good service under the most severe conditions of usage or exposure.

The builder, Burt Smith of Oregon, U.S.A., states that this special weatherproof plywood, known as Resnprest plywood, was chosen because it combined natural beauty and adaptability to smooth wall construction with permanence, strength, rigidity, greater insulation properties and increased resistance to insects and fungi. In particulars of cost it is revealed that the Resnprest plywood was exceedingly economical and by no means a luxury building material. The exterior walls for a $4,750 bungalow cost only $117 for materials with labour at $63, this being little more than one-fortieth the total cost.

Resnprest would appear to be well worthy of investigation by building contractors and architects on this side of the Atlantic as it is a distinct improvement on ordinary weatherboarding and would be very suitable for seaside bungalows, chalets, holiday camps and even caravans.

The building sheets could be used in conjunction with solid planks of impregnated wood if an all insect-and rot-proof structure were specified. The difficulty here, of course, would be the avoidance of nails as impregnated wood, such as Durisol and Permali, etc., cannot be nailed, but must be screwed. This, however, although naturally somewhat more costly, would undoubtedly mean a better-constructed house.

**Plastics as Structural Materials for Building Construction.**

Although the writers may be accused of false optimism in devoting space to a consideration of plastics as structural materials, they consider that synthetic materials may eventually be available to the builder for use instead of wood for joists, etc., and perhaps

even in place of steel for specialised purposes where metal is undesirable.

Already a plastic is being made in plank form, 6 in. maximum width, 30 ft. long or more and any desired thickness. The writers are referring to Dr. de Bruyne's Gordon Aerolite which is stated to be the strongest plastic yet made and a great improvement on de Bruyne's cord reinforced resin, which, it will be remembered, possessed remarkably good properties. The figures given for Gordon Aerolite (Paper read before R. Ae. S. Weybridge, Jan., 1939) are as follows:

| Tensile Strength. | Comp. Strength. | Young's Modulus. | Shear Strength. | Specific Gravity. |
|---|---|---|---|---|
| 45,000 | 24,000 | $6{\cdot}0 \times 10^6$ | 5,000 | .. |

At the present time Gordon Aerolite is only being produced in small quantities for experimental purposes in aircraft construction. Naturally its price is high, but under normal peace-time conditions it is reasonable to presume that manufacturing costs could be greatly reduced. Not only could this plastic be produced in exactly the right lengths for constructional purposes, but also moulded so that holes for bolts, screws, rivets, etc., could be formed and so save time and labour on the actual building job. For pre-fabricated or sectional buildings such a material appears to be very promising, especially for use in the tropics, where there is a definite need for a rot-proof and insect-proof light-weight building material such as Gordon Aerolite.

In comparison with steel, Gordon Aerolite is naturally considerably weaker, but comparing the ratio of physical strengths with specific gravity the figures are by no means so widely different, indeed, in the case of tensile strength the plastic is considerably better. The shear strength of the plastic is, however, much less than steel.

Comparison of Gordon Aerolite and Steel on Strength to Weight Basis

| | $t/p$ (lb. per in.$^2$). | $C/p$ (lb. per in.$^2$). | $E/p$ (lb. per in.$^2$). | $S/p$ (lb. per in.$^2$). |
|---|---|---|---|---|
| Gordon Aerolite | 31,500 | 16,800 | $4{\cdot}20 \times 10^6$ | 3,490 |
| Steel . . . . | 23,100 | 23,100 | $3{\cdot}85 \times 10^6$ | 13,500 |

$t$ = tensile strength. C = compressive strength. E = Young's Modulus. S = Shear strength. $p$ = specific gravity.

Plants of impregnated and compressed wood are also available, and reference to the physical properties of such materials as Durisol and Permali shows that they are very good, an important advantage being that the process of manufacture is readily adaptable and wood possessing high resistance to flexion, traction, etc., may be produced by merely altering the position of the laminæ. The importance of this adaptability of production needs little explanation as it should be obvious to the architect that it would be a great asset if he knew that materials were available able to resist special strains and stresses and also possessing the maximum rot resisting qualities. For churches, schools and public buildings designed to last for centuries the use of structural materials able to resist all wood-boring insects, such as the dreaded death-watch beetle, would surely be a great advantage.

The difficulty of using plastics such as Gordon Aerolite and impregnated and compressed wood has, of course, to be considered as these materials cannot be nailed or glued (except with great difficulty) and use has to be made almost exclusively of screws, bolts and special joints, such as the ingenious dowel joint invented by Dr. de Bruyne for the construction of aeroplane spars from Gordon Aerolite.

The use of plastics for structural purposes in building is at present only of academic interest, but there is already a growing conviction that at the normal peace-time rate of wood consumption our resources will not last indefinitely and it may, therefore, be in the interests of civilisation to make use of alternative materials. A good deal of work is being carried out in America on the use of wood waste for making lignin plastics and promising results have been obtained. There is no lack of cellulose unsuitable for building purposes and it may be that the development of lignin plastics would go a long way towards a wise conservation of our natural resources.

**Laminated Sheets for Panelling.**

These are now extensively employed for walls and surrounds in modern restaurants, hotels, cinemas, beauty parlours, shops and on luxury liners. For these purposes they are usually purchased as solid panels from $\frac{1}{16}$ in. thickness in a fairly extensive range of colours and usually two surfaces, full gloss and satin. In the case of light shades the top lamination or surface layer is

a urea impregnated material cemented down on to the phenol resin impregnated base. Blisterproof types have a thin diaphragm of metal immediately under the surface layer which carries away the heat and so prevents damage to the panel by cumulative heat.

Panels are usually screwed to the wall with self-tapping screws which are themselves generally covered over with a chromium-plated or stainless-steel band. In the case of circular pillars and curved work the thinner sheet, $\frac{1}{16}$ in., can be bent cold to an approximate radius of 18 in. or even smaller, depending on the height of the sheet. Where smaller radii are required, it is necessary to heat and preform the laminated sheet. Roanoid Ltd. recommend preforming their own material at 100° C., and while the material is still hot it should be placed in a form with a radius slightly smaller than is necessary for the finished curvature. The material must be clamped or otherwise held to this form until it is cooled. The heating should be done either on a steam-heated platen or in an oven. If the curved material is not placed in position immediately after removing from the form it should be placed in a support which will hold it to the approximate curved shape, as it has a tendency to straighten out if left exposed and not held to shape.

Advantages which can be claimed for laminated panelling may be summarised as follows :

1. Attractive and permanent colour effects.
2. Fire resistant.
3. Impervious to moisture.
4. Impervious to attack by wood-boring insects.
5. Not brittle and not liable to crack or craze.
6. Warm and pleasant to the touch owing to poor thermal conductivity.

As regards ability to resist warping and distortion, this is generally good and laminated panelling may now be specified by architects with increased confidence. It should, however, be realised that ability to resist dimensional changes depends very largely on how the sheet is fixed in position and the degree of stress it is subjected to. Perfectly flat surfaces do not usually give any trouble, but curved surfaces are sometimes difficult.

It is rather surprising that greater use has not been made of

laminated sheeting for panelling in hospitals, especially operating theatres, where there is a great need for a hygienic wall surface which is never really cold to the touch and can be kept perfectly clean with the absolute minimum of labour. Owing to the excellent heat-insulating properties of laminated sheet there is little or no fear of condensation.

Apart from the use of ordinary laminated sheeting in plain or mottled colours there is no reason why impregnated wood panelling should not be used. This also possesses good heat-insulating properties, is fire resistant and highly decorative. Standard woods used for impregnation are birch, beech and acacia, but other woods could be used to advantage and instead of employing a yellow- or orange-tinted phenolic resin a colourless urea resin might be used. The impregnated wood surface would be impervious to moisture and also wood-boring insects.

**Resin and Sand Compounds.**

Mixtures of phenolic resin and sand to form a workable kind of cement have been in use for some years now. They are employed generally for facing bricks, pointing and specialised decorative purposes in building construction. Probably the best known resin-sand preparation is Komrok which competes with concrete, plaster and magnesium oxychloride cements. This composition is made up of a silica filler (sand), pigment for colouring and a synthetic resin or binder which cures or polymerises on exposure to air. It has been used with some success for jointless flooring in commercial buildings, but it is particularly recommended for window surrounds. For this type of application Komrok is applied to the brick or concrete base in the form of a dough-like mass and spread on by means of a trowel. In the course of a few hours the resin has polymerised and the new form of stucco is perfectly hard and possesses a very smooth and attractive surface.

The writers are of the opinion that compositions of the type of Komrok offer great possibilities for tile-making in direct competition to those at present made of concrete and clay. Advantages which can be claimed for resin-sand tiles are more attractive colour effects and increased mechanical strength. One process has already been patented which makes use of a cheap silicious filler and a binder consisting of one to two per cent. of synthetic resin. The tile made from a composition similar to the above

has been tested. Under the cross-break test it gave a figure of 200 lb. per sq. in., whereas the specification for the concrete tile is only 125 lb. Dimensions of this tile were 10½ in. by 6½ in. by ½ in. and the weight about 1⅝ lb., against a concrete tile of 2–2¼ lb.

From the manufacturing angle the production of tiles similar to the above offers certain practical advantages, namely the omission of the high-temperature baking process necessary for all clay tiles. The resin-sand tile only requires baking at the very moderate temperature of 170° C., and it is possible that even this could be lowered very considerably or even omitted altogether, provided some kind of accelerator were added to the resin so as to enable polymerisation to be carried out within, say, a couple of hours. It should, of course, be remembered that concrete tiles do not require any baking, but, even so, they can be produced at a remarkably cheap rate, round about £2 10*s.* per 1,000, which is approximately the same as the resin-sand tiles.

The future of the plastic or part-plastic tile appears to lie in the use of a cheap resin-sand mixture and not in the use of an expensive thermo-setting moulding powder, as has been suggested. In order to prove economic the latter would have to be in the region of 2*d.* or 3*d.* per lb., instead of 6*d.* to 10*d.*, and to maintain output the moulding plant would certainly have to be very considerable. On the other hand, of course, the moulded tile, presuming that a standard thermo-setting resin were employed throughout, would possess a high resistance to moisture as well as excellent mechanical properties. The surface would be smooth and semi-lustrous and colours permanent. Probably the most important advantage which could be claimed by the all-plastic tile would be lightness in weight, so that some economies might well be made in the timber used for roof structures. It also seems as if the improved thermal insulating properties of the moulded tile would be an advantage, especially for use in the tropics, where any improvements in this direction would be very welcome. It should, of course, be realised that an all-plastic tile, as distinct from the more practical and economic resin-sand tile, can only be considered as a luxury item, but even so it might find certain specialised applications which would merit starting up a small pilot plant.

It has been suggested that, instead of using a pure phenolic resin varnish as a binder for mixing with the sand, an emulsion of

the resin in water might be employed. Whilst tentative experiments have shown this idea to be a distinct possibility, it is as well to point out that all tiles must, before acceptance, be able to stand up to the water-pressure test. The water-resistant properties of a phenolic resin emulsion sand mixture do not appear to be high enough to justify very high hopes regarding weathering properties.

No one appears to have tried a cheap urea-formaldehyde glue containing a suitable hardener, such as a working solution of Kaurit or Aerolite. If this were mixed with the sand, cold moulded or extruded on a tile-making machine and then dried, it is reasonable to suppose that the finished result would be impervious to water. This method, although purely theoretical, certainly does appear to possess some potential advantages which might be summarised as follows :

1. Wet sand could be used.
2. Mixing would be a good deal easier with an aqueous solution than a highly viscous phenolic resin.
3. Omission of any baking process would greatly accelerate production and cut down overheads.
4. Finished tile would be reasonably impervious to moisture.

It is, of course, obvious that difficulties would arise with this method, particularly with the control of polymerisation and the difficulty of ensuring that the mix did not start to set before it had been moulded or extruded. Difficulties foreseen do not, however, appear to be unsurmountable and the method not without some merit.

One of the secrets of the successful production of resin-sand mixtures is the grading and washing of the sand. Unless grading of the sand particles is carried out very thoroughly the finished tile is liable to have an uneven structure and prove unreliable in service. Washing is necessary to remove filth and sand, particularly the latter, which shows up as a white deposit on the surface of the cured and dried resin-sand compound.

**Laminated Sheet for Heat Insulation in the Tropics.**

In June, 1938, a demonstration was held at the London School of Hygiene and Tropical Medicine, London, of a specially constructed and air-conditioned chamber to be used as a rest room in

African gold mines and other places in the tropics where both temperature and humidity are such that considerable distress is caused to Europeans. This chamber or cubicle was made up of twenty-one separate panels of laminated sheet material each weighing about 27 lb. These panels were themselves built up in sandwich fashion of two sheets of Bakelite laminated material separated by a central diaphragm of reinforced aluminium foil. This was so arranged in position that a still air space separated it on both faces from the plastic sheets. The high heat-insulating value of these composite panels was due to the following factors:

1. Heat-reflective properties of reinforced aluminium foil.
2. Heat-insulating properties of laminated sheets.
3. Heat-insulating properties of still air spaces between foil and laminated sheets.

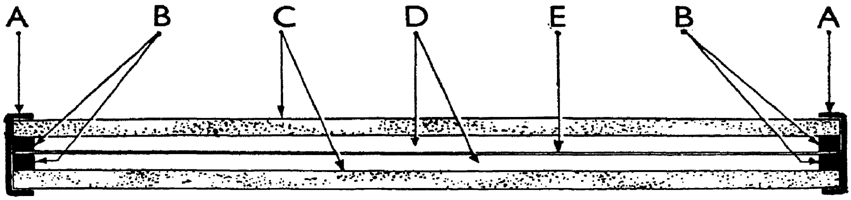
Under test, the insulating properties of the cubicle were so good that the air-conditioning system was able to run efficiently with only ½ h.p. motor and therefore operate very economically. Readings taken outside and inside the cubicle were as follows:

| *Outside Conditions.* | *Inside Conditions.* |
|---|---|
| Dry bulb, 100° F. | Dry bulb, 85° F. |
| Wet bulb, 90° F. | Wet bulb, 72·5° F. |
| Dew point, 87·5° F. | Dew point, 67·5° F. |
| Relative humidity, 69 per cent. | Relative humidity, 55 per cent. |

Judging from the successful working of this cubicle, it is likely that large industrial concerns working under notoriously bad atmospheric conditions will make use of laminated sheet for the shell of rest rooms, first-aid posts and offices, etc. Apart from the heat-insulating purposes of the laminated sheet, it is also impervious to moisture and under very humid conditions will not warp or, indeed, show signs of dimensional instability. Another very important advantage shared by the laminated sheet is that it is resistant to the attack of wood-boring insects, particularly white ants, and is also unfavourable to the growth of fungi owing, probably, to the presence of minute quantities of free phenol.

There seems no reason why panels made up of two laminated sheets with a central diaphragm of reinforced aluminium foil should not be used in general building construction in the tropics,

particularly for the ceilings of bungalows or of rooms immediately underneath slated or tiled roofs which are usually very hot indeed. The section shown illustrates the general method of building up these heat-insulating panels, the air space on either side of the diaphragm being $\frac{1}{4}$ in. to $\frac{1}{2}$ in. Tests at the Building Research




Heat-insulating panel incorporating Bakelite sheets.

A. Metal clip holding composite panel firmly in position.
B. Blocks separating diaphragm of reinforced aluminium foil from sheet of Bakelite laminated material.
C. Bakelite laminated sheets.
D. Air space.
E. Diaphragm of aluminium foil.

Station of the Department of Scientific and Industrial Research, as well as independent tests carried out by Dr. Crowden, the inventor of the reinforced aluminium foil, show that a 1-in. air space divided medially by a layer of the reinforced aluminium foil afforded protection against heat or cold as good as a layer of slab cork 1 in. in thickness or 13 in. of brick.

**Acrylic Resin for the Architect.**

In America, Lucite, the famous Du Pont methyl methacrylate resin, is now being extensively employed for interior decoration and furnishing in hotels, stores, restaurants, etc. In the April, 1940, issue of the *Du Pont Magazine*, there is an interesting account of the work done with this new and beautiful material in the realm of interior decoration, an excellent example of which is to be seen in the luxurious cocktail lounge of San Francisco's Hotel, St. Francis. Over 2,500 crystal-clear Lucite panels, each formed from a cast sheet, and in six pre-determined designs, were used to make the ceiling. Each panel was formed and fabricated to an allowable tolerance of $\frac{1}{16}$ of an inch and all were so carefully installed as to give the ceiling the appearance of one solid piece. Taking advantage of the edge-lighting and light transmission properties, striking effects are obtained by indirectly

flooding the ceiling with constantly changing coloured lights. Adding to the beauty of the room are the graceful bar stools perched on a metal core surrounded by Lucite rods.

Sak's Wilshire Boulevard store in Hollywood has employed large cast Lucite sheets for a gracefully curved, artistically-etched group of panels over the back bar in the cocktail lounge and café. By edge-lighting the panels with a neon tube placed along the top, the etchings stand out sharply and clearly. A balustrade at the store entrance is also decorated with thick, carved Lucite sheets. Another group of etched panels separates the cocktail bar from the lounge in the Hotel Woodstock in New York City. The panels, featuring scenes of the city, were made of this plastic because of its light weight, resistance to breakage and ability to be etched.

Several of Hollywood's new ultra-modern stores have found Lucite an ideal material for ornate light fixtures and chandeliers in keeping with the design of the store. In I. Magnin's, reading lamps have been formed from sheets and trimmed with rods, while gigantic chandeliers, partially of Lucite rods, illuminate several of the elaborate salons.

Railroad designers have been quick to recognise the potentialities of Lucite. One special lounge and buffet car on a crack Delaware, Lackawanna and Western Railroad train is cleverly divided by light-carrying columns made of Lucite tubes. At the base they are decorated with transparent flow boxes of the same material. On the Chicago and North-western's swift "400" train, Lucite has been used in bar cabinets and for shelving, adding effectively to the appearance of the special buffet car.

The ability of the material to withstand ordinary atmospheric conditions without apparent change, makes it applicable to exterior as well as interior uses. Already two years old is a set of terrace furniture with chair seats and backs made from halved tubes of the material for one of America's motor executives. A progressive firm of New York architects has specified Lucite for a two-storey centre decoration on the front of a proposed Pittsburg department-store building.

Perhaps the most rapidly expanding use of Lucite for interior decoration, however, is in the furniture field. Stores throughout the country are offering tables, vanity chairs and other pieces both of a standard line and their own design.

## BUILDING INDUSTRY

The following list is given as a guide to builders:

LIST OF SPECIFIC GRAVITIES OF PLASTICS AND COMPARATIVE MATERIALS

| | | | |
|---|---|---|---|
| Lead | 11·400 | Vinyl resin | |
| Copper | 8·890 | Casein | 33 |
| Nickel | 8·670 | Cellulose acetate | 1·27–1·63 |
| Steel | 7·84 | Phenolic cast resin | 1·27–1·32 |
| Iron | 7·22 | Rubber hard | 1·12–1·80 |
| Zinc | 7·19 | Acrylic resin | 1·18 |
| Portland cement | 3·10 | Lignum vitæ | 1·10 |
| Duralumin | 2·82 | Styrene resin | 1·06 |
| Aluminium | 2·70 | Mahogany | 0·90 |
| Phenolic resin. Mineral-filled | 1·70–2·09 | Teak | 0·85 |
| Urea - formaldehyde resin | 1·48–1·50 | Oak | 0·80 |
| Phenolic resin. Fabric-filled | 1·37–1·40 | Beech | 0·75 |
| Phenolic laminated | 1·34–1·55 | Maple | 0·70 |
| Phenolic resin. Wood flour | 1·34–1·52 | Elm | 0·67 |
| Cellulose nitrate | 1·35–1·60 | Walnut | 0·65 |
| | | Pine | 0·50 |
| | | Spruce | |
| | | Cork | 0·24 |
| | | Balsa | 0·144 |

## CHAPTER XI

# SYNTHETIC GLUES

THERE are about a dozen different kinds of synthetic adhesives already finding applications in modern industry. The most important are, of course, phenol-formaldehyde and urea-formaldehyde adhesives, which are now being generously used in the manufacture of plywood for aeronautical, shipbuilding and building purposes and for many types of stress assembly wood-work where an exceedingly strong bonding material possessing maximum resistance to moisture, insects and fungi is required. The urea and phenolic adhesives are very definite improvements on even the finest animal and vegetable glues and can be recommended for all types of woodwork where the strength requirement of the joint is high or where the wood has to possess maximum resistance to the weather. Their employment has made possible many new and promising uses for plywood, particularly in the construction of sectional buildings, which can be relied upon not to warp or suffer in any way from exposure to the elements. A promising outlet for both glue and plywood appears to be in the manufacture of improved or compressed wood made up of laminæ bonded together with layers of dry or liquid phenolic glue. This type of wood is already finding major uses in the aircraft industry for wooden airscrews, and its possibilities are also being examined by shipbuilders, engineers and architects.

The industrialist cannot afford to ignore the possibilities of synthetic adhesives as they make practical the development of many new commercial processes which require bonding agents possessing unusual properties. Take, for instance, the use of vinyl resins for sealing glass bricks and for the greatly improved safety-glass now being made in the United States and also Great Britain by the use of special vinyl polymers. The new vinyl and acrylic adhesives open up a new field of exploitation for sealing

agents requiring the maximum tenacity coupled with good powers of elasticity.

**Urea-Formaldehyde Glues.**

These consist of two ingredients ; the first is a transparent or white syrupy compound which is a condensation product formed by reacting urea with formaldehyde. This is the actual glue, but it has to be used in conjunction with a hardener, usually a weak acid, which acts as a catalyst in promoting rapid setting of the urea resin by converting it into a hard and inert compound possessing excellent adhesive or bonding properties. The hardener is a water white liquid, but it is often coloured so as to facilitate rapid identification. Whilst manufacturers only put out one actual urea resin or glue, they usually make available several different hardeners which are characterised by their abilities to harden or set the glue at different speeds or rates, or are developed specially for cold or hot pressing. Some of these hardeners are very rapid in their action and enable jointed members to be ready for machining and working twenty minutes or even less after application of the glue. The rapidity with which the hardener acts in promoting solidification of the resin is in direct ratio to its *p*H and the more powerful the acid the quicker is the setting time. By the use of hydrochloric acid it is possible to harden the glue in a few minutes, but when record speeds are attained by means of strong acids there is always a grave danger of the cellulose being damaged beyond the actual glue joint and so rendering the wood weak and liable to break or crack if subjected to sudden impact. Damage done in this way is not at first discernible as the glue joint itself may be perfectly strong and well able to stand up to all official requirements. It is only after a period of time that the weakness is revealed. The only safe method is to control the *p*H of the actual hardening process, so as to ensure that whilst conditions are favourable to rapid setting, they are not likely to introduce a hazard in the form of possible degradation of the cellulose cells in the timber.

There are two standard methods of using the hardeners as produced by the best-known manufacturers. In the case of hardeners for Beetle and Kaurit glues, these are usually used separately, that is, the prepared wooden surface is first treated with the hardener solution, dried and then coated with the glue, when it is

ready for actual setting under pressure. Aerolite hardeners, on the other hand, are usually mixed with the urea glue before use. It should, however, be realised that both types are adaptable and, if necessary, Beetle hardeners may be mixed with the glue before use, although this method is not usually advised. Whilst excellent joints can, and, indeed, are regularly made by cold pressing without the use of any heat, a small amount of heat is recommended, even if hot pressing, as such, is not carried out. Heat not only accelerates setting of the glue, but also regularises or standardises the action. In all cases of setting, either cold or hot, the resin does not attain maximum strength until several days have elapsed, when polymerisation is complete.

Films of urea glues are rather prone to crack and craze and that is why members to be jointed must be sanded so that there is no gap for the glue to bridge. The inability of urea glue to bridge gaps of $\frac{5}{1000}$ in. to $\frac{20}{1000}$ in. has always been a rather serious disadvantage, but, fortunately for the glue-using industries, it has now been largely overcome by the introduction of new hardeners. This enables gaps of $\frac{20}{1000}$ in. to be successfully bridged without any diminution in the shear strength of the joint, which even at this gap exceeds Air Ministry requirements. The introduction of this hardener represents a very great advance in synthetic glues, as by its use it is now possible to eliminate a lot of fine sanding so as to ensure that gaps between members do not exceed $\frac{2}{1000}$ in. This will be particularly appreciated in the aircraft industry, where urea glues are extensively employed. The following test results are given by Aero Research Ltd. for their special hardener.

| Gluing Conditions. | | Test Results. Apparent Shear Stress (lb. per in.) of Glued Surface. | Mean (lb. per in.). |
|---|---|---|---|
| Gap (in.). | Pressure (lb. per in.). | | |
| 0·020 | Nil | 1,264, 1,213, 1,275, 1,360, 1,200, 1,226 | 1,256 |
| 0·010 | Nil | 1,335, 1,240, 1,162, 1,227, 1,370, 1,560 | 1,316 |
| 0·005 | Nil | 1,124, 1,118, 1,201, 920, 1,015, 1,065 | 1,074 |

What advantages do urea glues possess over casein glues? Apart from the extra strength obtainable by the use of the former, the outstanding advantages are greatly increased resistance to

moisture penetration and complete immunity of the glued joint to the action of fungi and bacteria. In addition, urea glues set more rapidly than casein glues and are more adaptable to mass-production work in the aircraft and allied industries. The exigencies of war have opened up important new fields of application for the urea glues and, apart from their extensive use in the aircraft industry, they are utilised for making ammunition boxes, army huts and many other sectional buildings, resulting in great speed of production by eliminating use of nails or screws. A very important advantage which can be claimed for urea glues is that they can be used successfully on wood containing 0–25 per cent. moisture, provided the surfaces to be joined are perfectly dry. There is, therefore, no necessity to dry the wood before assembly or after gluing, as is the case with other types of glue. Another admirable feature of urea glue is that as it contains less than 10 per cent. moisture, which mainly combines with the actual resin during setting, there is no fear of distortion of the wood taking place due to the evaporation of an excessive amount of water present in the glue, as is, of course, the case with all animal and vegetable glues.

Urea glue is, of course, more expensive, weight for weight, than casein, but although it cannot safely be diluted with water to make it go further, it can be mixed with rye flour and such a mixture is in every way satisfactory, giving a joint superior in strength to that possible by the use of casein and with a slightly better water resistance. The flour glue mixture is very easy to brush and as its penetration is much less than with the untreated glue it is particularly suitable for gluing porous veneers which may be damaged by the use of the straight urea adhesive.

Although urea glue is a reasonably stable product, that is, it may be kept for three months or so in suitable containers in a cool place, it soon commences to deteriorate or harden if traces of alkali, acid or certain salts are present and that is why great care must be taken to use perfectly clean containers. In the case of those glues which have to be mixed with the hardener before use the remainder or surplus left after a day's work should not be returned to stock, but must be thrown away and the container cleaned out ready for use again next day.

Dealing briefly with methods of using urea glues, it is useful to consider the two commercial grades, Aerolite and Beetle. In the case of the former, the glue is mixed with the hardener, usually

100 parts of glue to 10 parts of hardener, but the proportions naturally vary with different types of hardener and different applications. Directly after, and, indeed, during addition of hardener to the glue, the mixture is well agitated by hand or by suitable mechanical means. The mixed glue is then applied by means of brush or mechanical spreader to one of the surfaces to be joined and the two wooden members clamped, screwed or bradded together in the usual way. Although setting of the glue can take place at normal room temperatures, the manufacturers recommend the use of a small amount of heat, say with an electric blanket, or other means. The use of a moderate heat eliminates uncertainty in the time of setting and speeds up production very considerably. Aero Research, Ltd., report that at room temperature of 15° C. or 60° F. the glue will remain usable for five hours, and joints will set overnight. At 90° C. or 195° F., which is the temperature generally used for plywood construction, the glue will set rock hard in five minutes. It is stated that the relation between speed of setting and temperature is the same as for the accumulation of money at compound interest. The above figures are quoted for a slow-acting hardener.

In modern aircraft construction, where the urea glue is used for jointing spars and other parts, it is now customary for heat to be applied locally to the joints by means of heated wires capable of being heated up to beyond 200° F. and the temperature thermostatically controlled.

The degree or finality of setting or hardening can be determined by prodding the small excess which has exuded from the joint and so determining its hardness and the finality of the cure.

The strength of Aerolite glue is such that it exceeds the shear strength of all woods and that the breaking load with this glue is about 25 per cent. greater than with casein.

Referring now to Beetle glue, this is available for use by both cold and hot processes. Dealing with the former, it is stated by the manufacturers that with ordinary glues about 6 lb. of water are applied to each 100 square feet; with Beetle the amount is only 1–1½ lb. The appropriate cold hardener is applied thinly to the prepared wood surface by means of a rubber sponge or a soft brush. About 1 lb. per 100 ft. should be applied. The treated surface is then allowed to dry for a minimum of thirty minutes and may, indeed, be stored for several days before gluing. The

actual urea glue is next applied to one of the surfaces of the wood at the rate of approximately $2\frac{1}{2}$–3 lb. of glue per 100 sq. ft., either by hand using brushes with stiff bristles or rubber rollers. Pressure must be applied within fifteen minutes of bringing the glued surface in contact with the hardener. When laying veneers, the veneer is coated with the cold hardener and allowed to dry overnight, so that the veneer gets thoroughly flat and shrinks again to its original size. The Beetle is then applied to the core or plywood. For special purposes the glue can be mixed with the hardener before use. Pressing should, wherever possible, be carried out at 20° C. and at this temperature pressure exercised by hydraulic or screw presses should be continued for one and a half to four hours depending on the type of hardener employed. In the case of Beetle mixed with rye flour, this must be very thoroughly mixed with the resin syrup. The strength of the glued joint depends on the proportion of filler used and if more than 100 parts rye flour to 100 parts of Beetle glue are used the strength of the joint is reduced and, of course, water resistance is much below that secured by use of straight Beetle. The mixture is, however, particularly recommended for applications where very strong joints are not absolutely essential. The hardener can be applied to the wooden surface before the flour and glue mixture or it may be mixed with the latter. The former method is usually preferred and the appropriate hardener is applied to one of the surfaces to be glued and allowed to dry thoroughly, then a mixture of Beetle glue and rye flour is applied either to the same or to the other surface. The glue film can be allowed to dry until it has become tacky before pressing or it may be pressed straight away. When the hardener is added to the mixture of flour and glue, it must not exceed 10 per cent. of the weight of the pure glue. The ready-mixed glue containing the hardener is applied to one of the surfaces to be glued, using $2\frac{1}{2}$ to $3\frac{1}{2}$ lb. per 100 sq. ft. The time of pressing is dependent on the type of hardener used and the proportion of flour present. The greater the amount of flour the longer the period of setting, assuming, of course, that the same amount of hardener is used.

The hot process produces a joint which is highly resistant to water and will even withstand boiling water. In this process Beetle glue is mixed with the special and appropriate hardener

which enables the glue to remain usable at room temperature for twenty-four to thirty hours. Approximately 2 lb. to 2 lb. 10 oz. of Beetle glue per 100 sq. ft. are necessary, but the thinner the coating of adhesive the better and quicker is the set. For certain types of work the use of a filler, such as calcium sulphate, is recommended to the extent of 20–50 parts per 100 of glue. Flour is also extensively used for work not specifying the maximum resistance of joints to water.

Pressing is carried out in heated presses at a temperature of 90–100° C. and a pressure of 28 lb. per sq. in. or more. It is stated that the time of pressing depends on the thickness of the wood to be joined. Generally the minimum time allowed is five minutes when using the special hot hardener liquid and eight minutes when using hot hardener powder, plus one minute for each millimetre of wood calculated to the deepest joint from the surface. Higher temperatures can, of course, be used and at a temperature of 130° C., two minutes' pressing is considered sufficient.

As mentioned previously, the most important application of urea glue is now being found in the aircraft industry, but widespread use is also being made of this adaptable adhesive in all woodworking industries. One of the most interesting applications of this type of adhesive comes from Germany, where, before the war, the Auto-Union A.G. were making wooden stress-carrying car bodies on a very large scale. At the end of 1938, 220,000 of such bodies had been built and many exported to tropical countries. Herr W. Oppermann (*V.D.I. Zeits.*, Vol. 83, p. 193) gives a very interesting account of the work carried out. Apparently, when the scheme first came into operation casein glue was used, but eventually discarded in favour of urea-formaldehyde or U.F. glue. Pressure needed for gluing was obtained either by clamps on the assembly jig or by wood screws, in the case of the 8 and 10 mm. plywood, and with nails for the 5 mm. skin. This, it is stated, proved satisfactory in every respect. The tenon joints of the frame were safeguarded by wood screws.

**Solid Urea-Formaldehyde Resins.**

The best-known solid U.F. glue is Lauxite, made by modifying the urea condensation product with zinc chloride. The adhesive is a white crystalline powder which is highly soluble in water, 1 part of glue being soluble in as low as 0·3, part of water.

For use it is usually dissolved in half its own weight of water, but proportion of the latter depends on the nature of the application. It is claimed that for hot pressing a lower temperature is required and that curing time is less than that of either phenolic or urea resin. Unlike the liquid urea glue, however, it cannot be used successfully in plywood manufacture unless the moisture content of plies is within 3–7 per cent. Reports of water and weather resistance appear to be very satisfactory. Economically, this new resin offers some advantages. The user buys a dry material to which he adds water as required. It is easy to transport and store and simple to prepare ready for use. As the powder may be weighed and its use, therefore, carefully controlled, this makes for standardisation of assembly, whereas, of course, it is difficult to weigh out the viscous syrupy urea resin. It is claimed that Lauxite spreads easier than urea resin and if this is so it is a definite advantage, as lack of good spreading properties is responsible for a considerable amount of waste. The easy spreadability of animal and vegetable glues is a very important property.

**Phenol-Formaldehyde Dry Gluefilm.**

This consists of a thin absorbent paper impregnated with an alcoholic solution of phenol-formaldehyde resin. It is made available in the form of a continuous sheet supplied in rolls. Under the action of heat the resin or resinoid, as it is commonly called, becomes fluid and on heating still further it sets to a hard, strong and water-resistant mass which acts as a very strong, but flexible bond between two sheets of wood. This type of adhesive can only be used under heat and pressure and finds its principal application in plywood manufacture, the plywood in this case being extensively employed in aircraft manufacture where a water-resistant, mould-proof and exceptionally strong, but non-brittle bonding agent is required. Plywood bonded with a good dry gluefilm can be soaked for long periods in water without deterioration and may even be boiled without damage to the joint. The bond is non-staining and is highly resistant to insects and fungi. Dry phenolic gluefilm is also widely used in the manufacture of improved wood for airscrew manufacture. The advantages of this dry gluefilm may be summarised as follows:

1. High strength of joint.
2. Maximum water resistance.

3. Maximum resistance to moisture, insects and fungi.
4. Exceptionally clean and simple to use.
5. Economy effected in use and also storage.
6. Enables work to be standardised.

One of the great advantages is the cleanliness of the bonding process and elimination of waste, as no scrap of gluefilm need be wasted; even odd pieces can be utilised and, of course, the sheet lasts for years without fear of deterioration. At one time a justifiable criticism of this type of adhesive was that it had to be kept in a dry, cool storeroom, otherwise the film hardened, probably due to polymerisation, and this interfered with the easy working and subsequent strength of the bond. It is claimed that modern gluefilms are not so susceptible to damp, but manufacturers advise that rolls should be stored upright in a dry place as damp tends to cause deterioration. Plywood bonded with one of the standard dry gluefilms is greatly superior to any other kind as it is entirely free from the tendency to warp, twist or split and its vastly superior water-resistant properties render it particularly suitable for the most drastic applications, such as sectional buildings, boats, interior decoration, motor bodies, aircraft, etc.

Two well-known forms of phenolic dry gluefilm are in regular use, Plybond and Tego Film. Bakelite Ltd., who manufacture Plybond, recommend its use for veneers with a moisture content of 7 to 10 per cent. The platen temperature varies from about 285–300° F. with a hydraulic pressure of 250–300 lb. per sq. in. Curing or pressing time varies and may be said to be governed by the thickness of the board produced and, of course, the conditions of setting, such as temperature and pressure. Bakelite recommend a period of three minutes plus one and a half minutes for each millimetre thickness of the finished board. Post-pressing conditions have to be regulated so that the moisture lost during hot pressing is returned to the wood. This is usually done by subjecting the glued wood to an atmosphere of steam or soaking in water.

Referring now to Tego gluefilm, the manufacturers, British Tego Gluefilm Ltd., subsidiary of The Micanite and Insulators Co. Ltd., state that successful bonding is dependent upon proper control of the following four conditions:

1. Moisture content of the veneers.
2. The temperature during pressing.

3. The bonding pressure.
4. The time under full pressure.

Moisture content must be from 8 to 12 per cent., with about 10 per cent. as the optimum. The curve shows a gradual rise in shear value from nil at 0·0 per cent. moisture to approximately 425 at 4 per cent. moisture to 450 at 6 per cent., then a drop down to 425 at 8 per cent. and a rise to the maximum of approximately 460 lb. per sq. in. at 10 per cent., with a stiff fall from that figure. Naturally, the most desirable moisture content for certain types of work differs quite considerably and every job has to be determined on its own merits.

After preparing the stock, so that it has the most suitable moisture content, the Tego gluefilm is cut into sheets so as to cover the area to be glued. For thick work two or more layers of gluefilm may be employed, or a thicker grade used ; there are, in fact, several different grades or weights of film. Aluminium sheets $\frac{1}{16}$ in. thick are placed on both sides of the assembled stack of veneer and the pressure applied immediately. Recommended pressures vary from about 120 to 300 lb. per sq. in., depending on the type of wood ; hard woods require a very much higher pressure than pine and low-density woods. The temperature should be approximately 290° F. or in excess of this figure and the pressure and heat maintained from five minutes up to twenty minutes or more according to the thickness. Completed plywood is allowed to remain overnight to cool and then seasoned.

**Liquid Phenolic Resin.**

Alcoholic solutions of phenol-formaldehyde resins are used for a number of purposes in industry, especially for the impregnation of textile material and paper to be utilised in the manufacture of electrical components. A very important development is the use of liquid phenolic resin in the manufacture of plywood. Karl Kopplin of Roddis Lumber & Veneer Co., in a paper read before the American Society of Mechanical Engineers, September 23, 1938, gave a very interesting account of recent work. He stated that the liquid glue which contained a catalyst was adaptable to standard glue-spreading methods and could be left in the spreader indefinitely without fear of premature hardening. Assembled

stock can be coated with the glue and then kept in stock for two or three weeks before hot pressing. Moisture content of plywood prior to pressing is held to a minimum and, in fact, the method of using the liquid glue does not differ in any important manner from the standard wet glue process favoured by manufacturers for many years past. The bond obtained by use of the liquid phenolic glue is highly resistant to water, even boiling water, insects and fungi. Its strength is also considerably greater than can be obtained by use of dry phenolic gluefilm. Tests carried out showed an increase in shear strength of liquid resin over dry film of 17·1 per cent. to 23·3 per cent., depending on the bonding time, the highest figure being secured with only four minutes' setting. Increase in fungi shear strength of liquid resin over dry film was 10 per cent. The low time necessary to effect perfect hardening is particularly significant and on test a four-minute cure was found ample for all commercial or aircraft purposes, being equal to a nine-minute dry film cure.

From the work so far carried out it would appear that the future of liquid phenolic glues in the aircraft and shipbuilding industries offers great promise.

**Cellulose Cements.**

Excellent cements may be made from cellulose esters and ethers, particularly cellulose nitrate and ethyl and methyl cellulose. The first-named is put up in small containers as a general household adhesive for sticking metal, wood, glass and practically every product; the shear strength, flexure and elongation of the joint is good. Ethyl cellulose cements are used where low flammability, toughness, waterproofness and heating properties are required, particularly for use with cloth, paper, foil and footwear. It can also be used in the manufacture of heat-fusible resin cements or water emulsions. Methyl cellulose is a comparatively new addition to the range of adhesives and under the name of Tylose it is finding similar uses to ordinary size, but has the advantage of being mould proof and more economical in use than the animal glue.

Commercial cellulose nitrate cements are usually made from film scrap which is cleaned, dried, dissolved in cheap solvents and various plasticisers added to give a non-brittle and elastic bonding material. Cements can also be made with acetate scrap by dis-

solving it in a mixture of acetone and benzene. This type of cement has not such good ageing properties as the one prepared with celluloid, but it is very necessary for use when fabricating shaped pieces in acetate sheet material. Ethyl cellulose is never used alone, but always in conjunction with various modifiers and plasticisers. Methyl cellulose, on the other hand, is merely soaked in hot water and allowed to swell, when it forms a paste-like mass ready for use.

**Acrylic and Vinyl Adhesives.**

Solvent solutions of these polymers, which may vary considerably in viscosity, are finding increasing applications for specialised purposes, such as for bonding glass, cloth, paper, leather and many other materials. The seal or bond is non-hardening in the sense that no cure takes place and one of its principal advantages is that heat sealing, which removes excess of solvent, produces an exceedingly tenacious and yet elastic film. Vinyl resin adhesives are particularly useful for sealing operations in the food industry as they are perfectly odourless, tasteless and stable under all conditions of use. Thus it is used for sealing milk cartons, attaching liners to bottle caps and closures and many other purposes for which ordinary commercial adhesives are unsuitable. Both acrylic and vinyl adhesives offer the solution to sealing problems hitherto considered impossible to solve. They are not, of course, suitable for use in the woodworking industries.

# CHAPTER XII

## SYNTHETIC RUBBER IN MODERN INDUSTRY

THE term "synthetic rubber" is an unfortunate one because although two groups of so-called "synthetic rubber," the butadiene polymers typified by Buna and the chloroprene polymers by neoprene, resemble natural rubber in chemical composition and structure, there are others whose molecule bears no resemblance to that of rubber. Such products as the polyvinyl resins known commercially as Koroseal, Mipolam, etc., alkylene polysulphides such as Thiokol and ethylene polymers like polythene all possess rubber-like properties and are often termed synthetic rubbers, yet they bear no real resemblance to natural rubber, although they replace it for petrol hose and cable sheathing, etc. Strictly speaking, it would be more correct to refer to all these compounds as rubber-like plastics.

The physical and chemical properties of all the synthetics differ appreciably in degree, whilst sharing more or less the same outstanding properties. Almost every product can be adapted or modified to meet special conditions of service and in the case of Koroseal and Mipolam, which are plasticised, a wide range of products are available. In the case of Koroseal, for instance, the elongation may be varied from 2 per cent. to 500 per cent. by increasing the plasticiser content. Polythene can also be altered or modified by plasticisation.

Referring briefly to the general characteristics of the range of synthetic rubber-like plastics, Buna appears to be the most rubbery of the series and possesses physical properties akin to rubber but with a greater resistance to heat, oil and chemicals. Neoprene is not quite as rubbery as Buna and its elasticity is not so great. On the other hand, however, it is more resistant to heat, oil, corona, ozone and sunlight and, generally speaking, has better ageing properties. Dr. W. J. S. Naunton in his book on *Synthetic*

*Rubber* states that vulcanised neoprene compounds resemble rubber compounds in :

1. Appearance.
2. Elasticity and extensibility.
3. Resilience.
4. Strength.
5. Abrasive resistance.

but are superior to rubber compounds because they :

1. Show a better resistance to the action of oils and fats (vegetable and mineral) and many solvents ;
2. Are more resistant to heat. Neoprene, unlike natural rubber, never softens under the action of heat up to 300° F. (i.e. it is not subject to reversion) ;
3. Age better in storage and sunlight ;
4. Show a better resistance to the action of ozone and oxygen ;
5. Have a lower permeability towards gases ;
6. Have a lower water absorption ; and
7. Show a better resistance to many corrosive chemicals.

Buna N or Perbunan is very rubbery and is said to resemble something between pale crepe and smoked sheet. It can be processed in the same way as ordinary plantation rubber.

Turning now to the next rubber-like compound of commercial importance, namely Thiokol, this is less rubbery than neoprene, possesses fair tensile strength, fair elongation at break but has a very high resistance to oil, aromatic solvents, chemicals, as well as corona, ozone and light. Thiokol is characterised by its pungent and unmistakable odour, which appears to have a mercaptan-like bouquet. Both Koroseal and Mipolam are available in a number of different forms, depending on the application. They are both characterised by an extremely high resistance to oil and chemicals, particularly strong oxidising agents such as nitric acid.

The most important of these synthetic compounds are utilised in modern industry because of their outstanding ability to resist the deteriorating effects of oil, solvents and chemicals, ozone, light and heat, coupled with an ability to withstand, with a few notable exceptions, about the same wear and tear as natural rubber. They are, however, more difficult to work or handle than natural rubber

and several times more expensive. In view of the greatly increased life of pipe-lines, gaskets, cable sheathing and printing rollers made of synthetic rubber-like materials, it is really an economy to stipulate Buna, neoprene, etc. To sum up quite briefly, it may be said that the synthetics can be recommended for those specialised applications where natural rubber does not and cannot, on account of its inheritory shortcomings, fulfil all requirements. There does not seem any real justification for their use where natural rubber gives perfect satisfaction and for this and other reasons it seems very doubtful whether synthetic rubber, such as Buna or the Russian and Italian products, will find any permanent place in the motor-tyre industry, except, of course, in an attempt at national self-sufficiency, which is, naturally, only a temporary measure.

One of the first and still the most important application of synthetic rubber was for making petrol and oil hose. This is now being made in very large quantities from Buna, neoprene, Thiokol, Koroseal and Mipolam, etc. The following advantages are claimed for a synthetic rubber-lined hose made of Thiokol:

1. Extremely low diffusion or evaporation loss—a lining at least eight times better in this respect than any other.
2. Greater flexibility at sub-zero temperatures.
3. No discoloration of spirit.
4. Unique resistance to the deteriorating action of petroleum, thus providing longer life.
5. Faster discharge with smooth inner lining makes possible quicker discharge.

The manufacturers of Thiokol give the following very interesting results of tests carried out on their ¾-in. hose:

| | |
|---|---|
| Soluble matter or petrol residue per 100 c.c. of petrol in twenty-four hours at 72° F. | 266·6 mg. |
| Sulphur in gasolene residue . . . | trace. |
| Loss of petrol or permeatic of petrol through 2 ft. of hose held twenty-four hours at 72° F. | 940·0 mg. |

From service reports it appears that whereas 8-in. rubber-lined hose used to discharge tank steamers containing petroleum usually lasts from twelve to eighteen months, Thiokol-lined hose has stood

up to more than two years of daily service and yet is in excellent condition to-day. Apart from the inconvenience due to a stoppage, a continual loss of spirit is caused which, over twelve months, may amount to quite an appreciable figure.

In the case of Koroseal no swelling takes place when immersed in oil, but some shrinking is caused in the soft varieties. Unlike both butadiene and neoprene, Koroseal and other members of the polyvinyl class are not resistant to organic compounds containing nitro or chlorine groups; aliphatic or aromatic ketones; aromatic amino compounds; lacquer solvents and acetic anhydride.

Allied to the use of synthetic rubber as a material for making hose is its application for the self-sealing bullet-proof petrol tank, which is a very important war-time production. Apparently the Germans are now using a special butadiene polymer with high swelling properties which is able to resist the inevitable breakdown and loss of strength, etc., suffered when natural rubber perishes as the result of the action of petrol. Experiments are being undertaken in this country with neoprene, used either alone or in conjunction with natural rubber, but the main difficulty is to make a tank of a reasonable weight—so far most British bullet-proof tanks have been several times heavier than the ordinary tank built of comparatively heavy-gauge duralumin.

According to Hayden and Krisman (*Ind. and Eng. Chem.*, 1933, **25**, 1219), oils of various origin exercise different degrees of swelling on neoprene and these workers divide them into three convenient groups, the first of which affects neoprene least, the second group slightly more and the third still more.

| Group I. | Group II. | Group III. |
|---|---|---|
| Petrol | Crude petroleum | Benzene and its homologues |
| Lubricating oils | Fuel oil | Solvent naphtha |
| Process oils | Diesel oil | Turpentine |
| Cottonseed oil | Coconut oil | Lacquer thinners |
| Olive oil | Fish oils | Carbon disulphide |
| Lard oil | Oleic acid | Carbon tetrachloride and other chlorinated solvents |
| Linseed oil | Paraffin oil | |
| Most other vegetable oils | | |

In benzene, neoprene increases in weight to the extent of approximately 150 per cent. in six hours and swelling does not increase appreciably for a long period after this. Butadiene

rubber, on the other hand, increases to the extent of nearly 175 per cent. in six hours and the curve takes a steady upward direction. In diesel oil, butadiene rubber and neoprene appear to act very similarly and in six hours about 30 per cent. increase in weight is registered for butadiene and 28 per cent. for neoprene, whereas natural rubber shows an increase of nearly 120 per cent. with the curve mounting rather steeply, whereas with the synthetics the curve rises only very gradually. Dr. Naunton states that the " oil resistance " of a compound cannot be taken as its resistance to swelling, but rather " the degree to which it retains its original characteristics during immersion in the types of oils and solvents that may be encountered in service at the maximum probable service temperatures."

It is of interest to consider briefly the resistance of Perbunan, the American form of Buna N, now being manufactured under licence by the Standard Oil Company of New Jersey, U.S.A., to various solvents. The following figures are given by Mr. I. E. Lightbrown (Chemical Division, Esso Laboratories, Standard Oil Development Company) in *The Rubber Age*, April, 1940.

Swelling of Perbunan in Comparison with Rubber
30 per cent. P-33 Stocks

| Liquid in which Sample Immersed | % Weight Increase after 24-day Immersion. | |
|---|---|---|
| | Rubber. | Perbunan. |
| *n*-heptane | 105 | No effect |
| Varsol | 160 | 20 |
| SAE 30 motor oil | 35 | No effect |
| White mineral oil (Nujol) | 90 | No effect |
| Benzene | 225 | 214 |
| Oleic acid | 115 | No effect |
| Amyl acetate | 210 | 53 |
| Cottonseed oil | 41 | No effect |
| Carbon tetrachloride | 600 | 160 |
| Diethyl ether | 115 | 23 |
| Acetone | No effect | 97 |
| Turpentine | 330 | 25 |

COMPARATIVE LOSS IN TENSILE STRENGTH OF PERBUNAN AND RUBBER AFTER 14 DAYS' IMMERSION IN GASOLINE
(Both Stocks contain 45 per cent. Gas Black on the Gum Content.)

| | Tensile (lb. per sq. in.). | |
|---|---|---|
| | Perbunan. | Rubber. |
| Before immersion | 4,600 | 4,200 |
| After immersion. | 2,650 | 0 |

One of the most important applications of synthetic rubber is in cable manufacture where there is a growing need for a perfectly stable and non-ageing insulating material with a high resistance to ozone, corona, light, heat, moisture and oil, etc. Synthetic rubber, such as neoprene, is particularly resistant to ozone and does not crack or pit in the same way as ordinary rubber. As regards heat, neoprene, containing no ingredients other than those required for vulcanisation, will not continue to burn when once the source of heat is removed; inert fillers tend to improve fire resistance. Fire-resisting cables are now being made and some of the best known consist of two layers, an inner one of high insulating pure vulcanised rubber and an outer layer of neoprene. The manufacture of this type of cable is covered by B.P. 499908.

Yet another use for the synthetic rubber materials is to be found in the printing industry, where they are now being used for rollers and plates. Neoprene, for instance, has a marked resistance to printing oils and possesses a very much longer life than natural rubber; it is also very serviceable for making blocks. In a lecture given by Mr. Robert B. Clarke in Stationers Hall, London, 1939, it was stated that examination of commercial and newspaper rollers made from neoprene shows that very little grinding is required for refinishing, because inks and washing solutions do not penetrate deeply. Rollers are in use for lithographic, offset and ordinary printing. Thiokol is also used with great success in printing, especially speciality printing on glass, metal, sandpaper, plastics and other difficult surfaces. It is claimed that the use of Thiokol plates enables a very high degree of accuracy in printing to be attained. In making Thiokol plates a sheet of matrix board, previously heated, is placed over the type forme or

engraving, very much in the same way as when making a stereotype matrix. Over this in turn is placed a thin sheet of tin, brass or steel to prevent the matrix from sticking to the top of the press, pressure is applied and the matrix is taken from the forme and cleaned off for plate making. A charge of the Thiokol in powder form, as much as is needed to make the plate, is then spread over the matrix, pressure is applied again, usually in a hydraulic press, and in about six minutes the plate is made. After trimming and mounting it is ready to put on the press. Thirty-five minutes, it is stated, is liberal time for making a plate from start to finish.

A considerable amount of Buna, neoprene, Thiokol, Koroseal, etc., is being used in the production of gaskets for use in motor-car manufacture, where oil sealing has necessarily to be of a very high order. Another very promising outlet for synthetic rubber-like compounds is in the production of oil-proof belts used in paper mills, oil refineries, chemical plants, tanneries, etc., where bad oil conditions are known to exist. Oil and grease make both leather and rubber composition belts slip and makes necessary constant maintenance work in tightening slack belts. Neoprene is also being used very successfully in the manufacture of oil resistant conveyor belts in place of the ordinary type of rubber impregnated material.

In the chemical field synthetic rubber is finding many new uses, thus Thiokol is used in conjunction with sulphur cement for bonding brick-built acid baths so as to prevent the attack of the acid on the cement usually employed for holding the bricks together. Neoprene dipped gloves and footwear are in regular use among chemical workers and neoprene is also being used for bonding to metal plant. Both Mipolam and Koroseal are extensively used: the former for making special chemical plant to resist nitric acid and the latter for lining tanks, drums, and centrifugal baskets. Koroseal is being employed for use with mixtures of nitric and hydrofluoric acid and apparently gives full satisfaction.

**Neoprene and Natural Rubber.**

The following comparative data are taken from the paper by B. J. Habgood, B.Sc., A.I.C., A.I.R.I.(Sc.), entitled "The Chemist and the Ship," presented by J. E. Holmstrom, B.Sc., Ph.D., Assoc. M.Inst.C.E. and published in the *Transactions of the Institute of Marine Engineers*:

## TABLE I

| | Rubber. | Neoprene. |
|---|---|---|
| Hardness (shore) | 60 | 60 |
| Tensile strength (kg. per cm.$^2$) | 216 | 224 |
| Elongation per cent. at break | 625 | 602 |
| Resilience per cent. | 63–65 | 63–65 |
| Abrasion loss | 0·110 | 0·110 |
| Fatigue flexing | 268 | over 1,000 |
| Per cent. swelling at 70° Cent. in— | | |
| Diesel oil | 480 | 58 |
| Transformer oil | 275 | 15 |
| Mobiloil BB | 104 | 4 |

## TABLE II

OXYGEN BOMB AGEING AT 70° CENT. AT 300 LB. PER SQUARE INCH OXYGEN PRESSURE

| | Tensile (kg. per cm.$^2$). | Rubber (elongation %). | Hardness. | Tensile (kg. per cm.$^2$). | Neoprene (elonga-tion %). | Hardness. |
|---|---|---|---|---|---|---|
| Unaged | 216 | 625 | 60 | 224 | 602 | 68 |
| 6 days | 86 | 366 | 64 | 167 | 448 | 72 |
| 12 days | 34 | 132 | 83 | 157 | 378 | 74 |
| 18 days | perished | perished | 100 | 132 | 313 | 77 |

## TABLE III

GEER OVEN AGEING IN AIR IN 70° CENT.

| | Tensile (kg. per cm.$^2$). | Rubber (elongation %). | Hardness. | Tensile (kg. per cm.$^2$). | Neoprene (elonga-tion %). | Hardness. |
|---|---|---|---|---|---|---|
| Unaged | 246 | 625 | 60 | 224 | 602 | 68 |
| 3 weeks | 265 | 506 | — | 249 | 496 | — |
| 6 weeks | 206 | 401 | 67 | 241 | 422 | 72 |
| 12 weeks | 41 | 135 | 70 | 200 | 280 | 80 |

TABLE IV

COMPARATIVE ELECTRICAL PROPERTIES OF RUBBER AND NEOPRENE

| | Vulcanised Rubber. | Vulcanised Neoprene. |
|---|---|---|
| Volume resistivity ohms. per cm.$^3$ | $1{\cdot}35 \times 10^{15}$ | $1 \times 10^{15}$ |
| Dielectric constant | 2·3 | 5 |
| Breakdown strength kv./mm. | 30 | 10 |
| Power factor (radio frequency) | 2·1 | 8 |

**Chlorinated Rubber.**

This modification of ordinary rubber has been receiving a good deal of attention in the industrial field and already such products as "Tornesite" and "Alloprene" are being utilised for specialised applications. This new product, which contains 65 to 66 per cent. of chlorine, is non-inflammable, possesses good resistance to aqueous alkalis and acids and, according to Sir Gilbert Morgan in his Presidential address to the Institute of the Plastics Industry, October 21st, 1937, has valuable electrical properties (power factor 0·003; dielectric constant 3·0 to 3·4, breakdown voltage 2,500 volts per mil.).

In commercial form chlorinated rubber is a colourless amorphous powder, which is graded and sold in terms of the viscosity of its solution in organic solvents. In an article in *The Gas World*, November 4, 1937, by Sir Gilbert Morgan and Dr. D. Pratt, the authors state that although the chief and obvious use of chlorinated rubber was in the paint industry a good deal of attention had been given to its development for insulating purposes, owing to a peculiar property it possesses of assuming a vesicular form. The expanded modification of chlorinated rubber is effected by submitting the material at 140° C. to pressure which is quickly released at the end of the moulding period. At the Chemical Research Laboratory this property has been exploited for the production of special laminated products. Chlorinated rubber when mixed with asbestos or mica may also be moulded to form various electrical components which can be machined with comparative ease. Sir Gilbert Morgan has suggested that as chlorinated rubber mouldings are promising heat, sound and electrical insulators and are not affected by long immersion in water it is

possible that uses will be found for them as refrigerator packings, sound-proofing panels or as fillings for lifebelts.

One of the most interesting and potentially important uses of chlorinated rubber is for the production of transparent sheets or mouldings. The former can be produced by dissolving the rubber in benzene or carbon tetrachloride and allowing the solvent to evaporate. Transparent mouldings are possible if compacted in a mould under pressure of 1 ton per square inch at 115–120° C. and the pressure is retained while the mould is cooled to approximately 70° C.

## CHAPTER XIII

# FANCY GOODS TRADE

A CONSIDERABLE quantity of plastic material is used in the fancy-goods trade for a wide miscellany of purposes, such as jewellery and dress ornaments, toilet ware, nursery goods, picnic outfits, drinking vessels and various domestic accessories, certain types of hardware goods, desk and office fittings and literally hundreds of other items of varying importance.

Plastics in the form of celluloid were originally used towards the end of the nineteenth century as a substitute for ivory, tortoise-shell, mother-of-pearl and coral, which were great favourites with our Victorian grandmothers as materials for dressing-table accessories. Celluloid was popular with manufacturers because of its low price in comparison with natural materials and because it was readily adaptable to methods used in the fabrication of ivory and tortoise-shell, that is, it could be welded under heat and pressure to give configurated sheets and shapes suitable for making up into brush and mirror backs, combs and other items.

Although fashions have changed very considerably since the days of waxed fruit and antimacassars, celluloid is still the favourite material of the toilet goods manufacturer and it is no exaggeration to say that at least 90 per cent. of toilet goods now being produced are made of celluloid. The popularity of this, the oldest plastic, is due to several reasons.

1. Cheap to buy and economical and easy to work.
2. Available in a very large number of decorative and coloured surfaces.
3. Possesses good ageing properties.

The main disadvantage of celluloid is, of course, its high inflammability and many tragic accidents have occurred through ignorance of this fact. The slight camphoraceous smell of celluloid, which

is noticeable when the fabricated article is first purchased, seldom lasts long and can hardly be called a disadvantage.

The most popular finishes of celluloid for toilet goods are demi-blond or imitation tortoise-shell, mottled and pearl, but apart from these standard shades, a very extensive range of plain and variegated colours (opaque and translucent) is available. Blanks are shaped on profiling machines and the moulded shapes cemented together round a plywood centre. A considerable amount of work, particularly for toilet mirrors, is done by blowing air between two shaped sheets of celluloid in a mould so as to form a hollow frame.

Cellulose acetate is used to a small extent in the manufacture of toilet ware, particularly for nursery goods, where the safety factor is always of great importance. Thus, teething rings, rattles and, to a limited extent, toilet sets are now being moulded of non-flam material. Apart from the fact that acetate is more expensive than celluloid, it is not quite as easy to work as the latter material, is not available in such a catholic range of colours and has not such good ageing properties as celluloid. These disadvantages, the extent of which may be considered unappreciable in a number of cases, are generally considered to be responsible for the fact that acetate has lagged behind celluloid in the fancy-goods trade. The main reason is, of course, the price, as the finished price is cut to such an extent that even a few pence extra a pound would make it difficult to compete in the cheap trade and, after all, the bulk of the celluloid toilet sets are made specially for the working-class market.

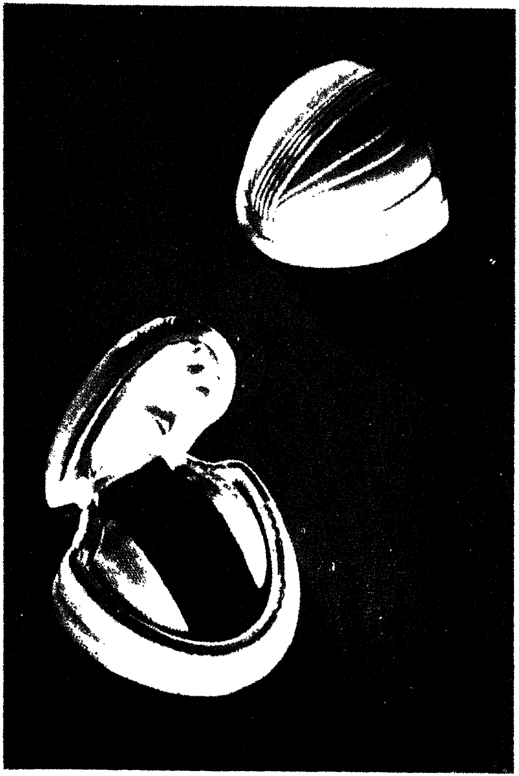
A great deal has been said and written about the advisability or otherwise of using celluloid for toilet sets, including baby ware, owing to the high inflammability of celluloid. Whilst not wishing to take an active part in this highly controversial argument, the authors do feel that the fact should be known that a certain amount has been done to lower the burning rate of celluloid, and present-day celluloid can justly claim to be slightly less inflammable than the material produced twenty years ago. It will be remembered that the Committee which was set up in 1937 to enquire into the use of celluloid for toys and toilet ware came to the conclusion that there was not sufficient evidence to merit the restriction or prohibition of celluloid goods. Statistics in the London Fire Brigade area show that between 1914 and 1936 there were 97,019

fires, of which only 15 were caused by celluloid. As for fatal injuries due to celluloid burning, there were two out of 1,745 child fatalities and one out of 7,691 adult fatalities. There is no denying, of course, that celluloid is a potentially dangerous material, but before damning it out of hand, there must be some segregation of applications. For toilet sets and a large proportion of fancy goods, celluloid would appear to be quite safe under the normal conditions of use, but for toys, particularly dolls, celluloid is not recommended and the far safer acetate should be used.

Celluloid finds its most important application in the hardware trade, where it is used for knife-handles and is, indeed, one of the few materials able to stand up to the gruelling conditions of service. Experiments carried out with moulded and cast knife-handles have not been entirely successful as they crack and craze in use, especially when subjected to continual washing up in alkaline wash water. The use of celluloid for knife-handles is one rather striking example where the synthetic product is even superior to the natural one, as ivory discolours quicker than the plastic. Celluloid knife-handles adhere tenaciously to the actual metal prong of the knife and it is very seldom indeed that they break away, whereas moulded handles, particularly those made of urea resins, are liable to swell and eventually leave the metal.

Another important outlet for celluloid in the fancy-goods trade is for fountain-pen barrels. The bulk of these are now made of this plastic, which is excellent for the purpose, as it combines light weight and pleasing warmth with good finish and permanent and attractive colouring. Other uses for celluloid include piano and accordion keys, decorations or trim for accordions, etc., electric accumulator cases, frames for cheap sun-glasses, tooth-brush handles, nail-brushes, heel-covers, solid heels, shoe forms, eyelets, etc.

A large number of drinking-vessels are being moulded of plastics, urea-formaldehyde resin being generally preferred, owing to its complete freedom from any trace of taste or smell. The majority of these moulded items intended to hold foods are designed specially for the nursery or for use on picnics. These, on the whole, have proved perfectly satisfactory, especially as it will be admitted that plastics have proved an immense boon in a market that requires a low-priced article. It should be remembered by those who quarrel with the apparent fragility of some of



Moulded watch display cases of Plaskon (urea-resin).

Injection moulded coat-hanger.
(Major Award, Modern Plastics Competition, 1939.)

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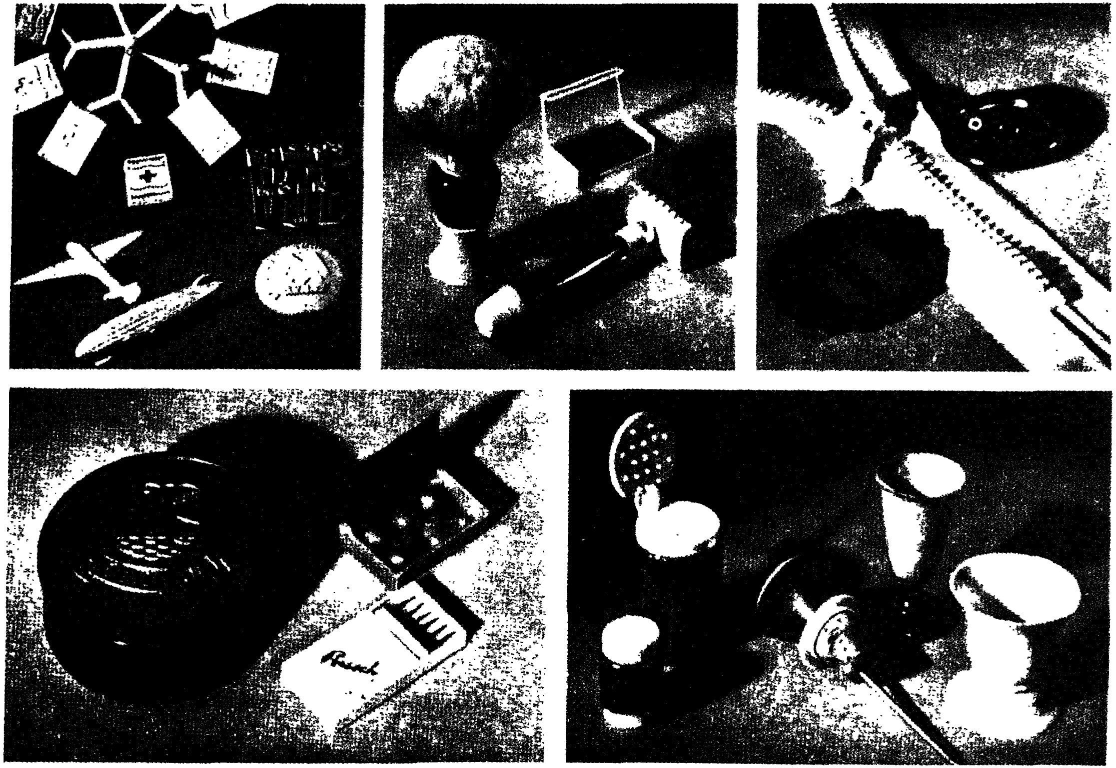

Examples of goods made in Germany in 1938 from Trolitul polystyrene resin by injection.

the tumblers, etc., which they have used that the plastics industry can produce a stronger material at a slightly increased price.

Cheap goods and badly made will not, as a rule, be strong enough to stand up to the severe conditions of regular use, but good-quality mouldings are obtainable at a reasonable price and they can be trusted to give excellent service. To overcome the tendency of urea plastics to absorb moisture from foodstuffs and so swell and become distorted, a desirable development would appear to be a combination of glass and plastics, the glass being used for the actual food container and the plastic for the outside shell or vehicle for the container.

Advantages which can be claimed for the moulded cup or mug, dish, etc., over a similar one made of glass or ceramics, include greater lightness and, therefore, ease of handling for young children ; greater safety factor, as even when the moulded article is broken it does not splinter and the broken vessel is not likely to cause cuts ; added attractiveness, due to the variety of colours which may be used. Practical experience seems to indicate that there is a considerable difference in the comparative life of plastics under varying conditions of service. Thus, in the case of a condiment set made up of three pieces, salt, pepper and mustard, the first two give complete satisfaction, but the mustard often causes the lid of the pot to swell so that it becomes difficult, if not impossible, to screw on to the pot. For dry goods, therefore, no difficulty should be experienced, but for liquids and pastes, etc., containing aqueous or acidic foods a certain amount of distortion, due to moisture absorption, is liable to occur, the extent of which being determined by the character of the resin and the length of the exposure to the food in question. For dry foods, such as tea, coffee, cocoa, biscuits, plastics would appear to be ideal and it is rather surprising that containers for these are not in regular use. Quite recently the methylmethacrylate resins, such as Plexiglas, have been used in Germany for serving spoons, sugar-tongs, etc., all of which were previously fabricated of metal. There seems little doubt that these glass-clear resins are very suitable for this purpose, as they not only look hygienic and attractive, but satisfy all the canons of the table and kitchen ; in the latter they are completely unaffected by soap and ordinary washing-up waters.

Plastics are obviously fitted for use in the toy trade and they fulfil all practical requirements for a number of best-selling lines,

particularly dolls and models of various kinds, including soldiers. Dolls are made either of celluloid or cellulose acetate by a simple process entailing the cementing together of two moulded halves, various coloured effects being produced by handwork. Model aeroplanes, soldiers, guns and all the popular armaments of the nursery can be made up of individually moulded items of cellulose acetate produced by means of modern high output injection moulding machines or simple hand presses. Cellulose acetate is ideal for this purpose because of its lightness, wide range of colours, resilience and shock-resisting properties, which render toys able to stand up to plenty of hard service without cracking, and the fact that it can be easily cemented, which facilitates assembly. There is no need to use best-quality acetate for this purpose, as scrap material serves the purpose equally well and is, of course, a good deal cheaper to buy in the first instance. An interesting development in the toy trade is the success of plastic building sets, made up of units moulded of phenol-formaldehyde and including bases or large area parts made of laminated sheet. These units are strong, rigid and permanently coloured, the last-named characteristic being a great asset as most painted wood or metal parts lose their colour after a few months of use. Plastics appear to be very suitable for building sets and no doubt increasing use will be made of them for this purpose as a growing market exists for toys of the meccano type.

The above remarks are mainly concerned with the selling or consumer side of the toy trade, but it is as well to remind manufacturers that whilst plastics are in every way economic materials for high output, they are not suitable for use for special lines not likely to enjoy large sales. When toys are being produced on mass-production lines in metal the number of individual processes may number four or five. Thus the sheet metal is stamped out in the various shapes, these are assembled, polished or prepared for spraying, sprayed and dried. In the case of plastics, the moulding is taken from the press and after removing the flash, a matter of a few moments only, the piece is ready for assembly, no spraying, painting or drying being necessary. This reduction in manufacturing processes means an economy of labour, use of a smaller factory space and reduction of overheads. But against this must be reckoned the increased price of material and the relatively high cost of jigs and tools, etc., not to mention the initial

cost of expensive presses. On long runs, however, manufacturers with experience of plastics agree that they do make possible a worthwhile reduction in the cost of production and, moreover, render practical the production of intricate shapes which could not be made in any other material on mass-production lines.

The success of the plastic toy from the manufacturing angle depends to a large extent on the development of a design adapted to moulding technique. It is a fact that some manufacturers with good and potentially profitable ideas fall down when it comes to the translation of their ideas into a practical moulded form. They forget that shapes that can be easily and successfully made in metal and wood are often quite unsuitable for plastics and it is not sufficient merely to carry out small alterations to the basic design. This usually results in a compromise which has all the look of a mediocrity and thus fails to catch the eye. The only real solution to the problem lies in the enlistment of the services of an experienced plastics designer who possesses the skill, experience and imagination required to transmute a typically metal or wooden shape into a plastic one. Emphasis should be laid on the experience of the designer, as only a man who thoroughly understands moulding technique can successfully grapple with the problem and effect economies in tool costs without sacrificing any essential feature of the design. Incidentally, production figures are influenced very considerably by the design and the ability of the moulding powder to flow evenly throughout the mould and for the moulding to leave the mould cleanly and easily.

Apart from the use of celluloid and cellulose acetate in the manufacture of fancy goods, particularly toilet ware, phenol-formaldehyde and urea resins, cast resin, methyl methacrylate and vinyl polymers are also used. The first named finds only a limited application, owing to its obvious colour limitations, but urea resin is extensively employed for all kinds of cheap bathroom and dressing-table accessories such as hair tidies, jewel caskets, denture-baths, eye-baths and other small items in white or pastel tints. Cast resin is available in an infinite variety of colours, ranging from imitation onyx, marble, ivory, tortoise-shell, to jet black. Transparent, translucent and opaque colours are all obtainable. This plastic is supplied in sheets, rods and tubes, all of which can be fabricated by means of standard wood- and metal-working machinery. The extruded tubes are, in many instances, readily

adaptable to the fabrication of bangles and other standard extruded shapes lend themselves to specialised production with equal adaptability. The material can also be cast in lead moulds and a high finish is obtained which requires very little polishing. A certain number of luxury items are now moulded of powdered methyl methacrylate resin or fabricated from rod, tube and sheet, but naturally these are rather expensive. They are, so far, only available in the glass clear resin, but this necessary limitation does not detract from the beauty of the finished work. In America a growing number of toilet items are being moulded of vinyl resins. Here again the transparent grade is the only one available, but it is reported that a healthy demand exists in the quality market for these more exclusive plastics.

It will thus be apparent that the range of plastics is now so extensive that every reasonable requirement can be catered for. Although the cheapest class of toilet goods, etc., is made of celluloid, really high-quality productions are being turned out of this plastic, which has excellent mechanical strength and is in every way a hard-wearing material. Take, for instance, the hand-cut celluloid comb. This stands up to wear far better than any other material and, indeed, cannot be surpassed for general serviceability. Cellulose acetate is slightly more expensive than the nitrate, but it is not so easy to work nor is it available in such varied and attractive colours. The thermo-setting resins are cheap when considered on mass-production lines, but uneconomical for series production, the urea resin being slightly more expensive than the phenolic. Cast resin is more costly than any of those so far mentioned, but cheaper than the methyl methacrylate and vinyl polymers.

It is of interest to note that nylon bristles are now being used for toothbrushes and hairbrushes in place of natural bristles, usually Siberian hog's bristles, and practical tests so far carried out indicate that the synthetic product has a much longer useful life than the natural fibre, which absorbs water fairly rapidly. Nylon bristles are sold in the United States under the name of "Exton." It is now being manufactured in Great Britain.

## CHAPTER XIV

# FURNITURE MANUFACTURE

THERE are several forms of plastics used by the modern cabinet maker, the most important being laminated sheet in the form of decorative veneers, large moulded units for table tops, moulded and cast door furniture, extruded rod or strip for table edging and synthetic resin for plywood manufacture and various joining processes.

Generally speaking, the cabinet maker is not particularly favourable to the use of plastics, as he is apt to compare them with wood, very much to their disadvantage. True, plastics do not possess the beautiful configuration of selected hardwoods, but some of the latest laminates which have a top surface of impregnated natural wood veneers, tapestry, fabric, fancy wallpaper, etc., are quite unique and open up many promising possibilities, especially in the manufacture of built-in furniture. Plastics render available gay colours, some of which are very attractive and others dull and mediocre. Whilst it is a fact that artificial colours have to be handled with great care when used in conjunction with the more delicate colours of natural woods, it is possible to arrive at a pleasing harmony, now that such a catholic range of grain effects and colours have been made available. A practical difficulty facing the cabinet maker using large area veneers is their liability to warp. This is not due to any inherent defect of the veneer, but rather to poor bonding and the use of unsuitable plywood bases. Provided proper care is taken there is no reason why plastic-surfaced furniture should suffer any dimensional change, but it is a fact that several small concerns have been discouraged by the results obtained with laminated sheet.

Even the most enthusiastic exponent of plastics can hardly expect them to be absorbed in a new industry without the accompaniment of various difficulties. These growing pains are, however, healthy signs of life and only perseverance and enthusiasm

are required to open up worthwhile applications. A promising outlet for plastics in furniture manufacture is the use of interchangeable moulded table-tops and other pieces, but, naturally, the exploitation of such mouldings by the cabinet maker is somewhat limited owing to obvious restrictions in their size. The real future of plastics lies in the use of laminated sheets, veneers and impregnated woods.

One of the most interesting developments is the use of real wood veneers impregnated with urea resin, which preserves the natural beauty of the wood and renders its surface impervious to water, heat, etc. Parkwood-Textolite, made by the General Electric Company, U.S.A., is a successful commercial laminated sheet made up of contrasting woven laminated wood veneers. This material has been used in America to great advantage for table-tops. We have, indeed, to look to America for the most important developments in the field of decorative laminates, as generous use has been made of them in hotels, restaurants, commercial buildings, trains, air liners and even private homes. In this country a very conservative attitude has been taken towards plastic furniture, but happily its acceptance by some of the leading railway and shipping companies is encouraging business houses to reconsider its claims.

Apart from the use of decorative veneers there seems no reason why laminated sheet should not be used for moulding or, rather, pressing out articles of furniture, such as small chairs and sections of sideboards, tables, bookcases and, indeed, many other necessities of the modern home. To those who immediately discount these suggestions as being merely imaginative, the writers would point out that the Timm trainer has been constructed with a completely moulded fuselage of impregnated plywood and the now well-known Clarke experimental aeroplane has a fuselage and wings moulded of laminated material. In the face of these achievements there seems no legitimate reason why similar material should not be used for furniture manufacture. The articles would, of course, have to be simply designed so as to render possible and economic the moulding process, but as so-called modernistic furniture is in demand for furnishing small luxury flats and modern houses, this should not prove any obstacle from the selling angle. Briefly the method of manufacture would be as follows. The impregnated and dried plywood, before poly-

merisation, would be stamped or cut out, using standard templates or patterns. The pieces would then be pressed in large hydraulic presses to the desired shape. After a slight finishing of the edges of the shaped pieces they could be joined together, and further necessary work undertaken to complete assembly. Naturally very large and expensive presses would be required for the moulding or forming and possibly it is this large initial outlay that frightens off possible experimenters. For a year or so experiments have been carried out on the moulding of seats for pilots in military planes, using a special form of impregnated paper, but it is uncertain how far these experiments have developed.

**Moulded Units.**

Moulded table-tops for dumb-waiters and occasional tables are in use to a small extent in licensed premises and cafés, etc. One of the most interesting characteristics of a moulded table-top is its adaptability. It can be fitted with a range of different styles or types of legs and enables the furniture manufacturer to vary his designs according to seasonable fluctuations, whilst taking full advantage of the standardisation of the moulded top. The mouldings are of wood-filled phenol-formaldehyde resin and are usually supplied in black and dark colours. Black is the most serviceable and popular.

The spiritual home of the moulded table-top is, of course, France, where the number of cafés runs into tens, if not hundreds of thousands, and since each café contains anything from ten to one hundred tables, the potential market is very large. Actual use of moulded table-tops is very extensive and it is rare to see in Paris or elsewhere the old-fashioned marble or metal top, which always seems so unwieldy and top heavy, and even the glass-topped table is something rather unusual, except in the old-fashioned or very expensive cafés, which choose special wooden tables.

Moulded table-tops have been welcomed in France not only because of their lightness, which saves both time and energy in moving the tables about, but also because of ease of cleaning, absence of staining due to water, alcohol and heat, and also beauty and permanence of colour.

There would appear to be an excellent export market for moulding concerns in Great Britain or the United States who have connections in Latin-American countries and the tropics where

out-door café life is common. France, Spain, Mexico and South American Republics would under normal conditions prove attractive potential markets, so, indeed, would Italy, were it not for the fact that marble is so cheap and the marble workers expert at their craft and deplorably low paid.

A recent development in England by Moulded Furniture Ltd., an associate company of Ashdowns Ltd., of St. Helens, Lancashire, is that of producing fireside furniture ; moulded fire-curbs, fire-screens, etc. A fair success was achieved, although not as great as was hoped. Certainly the effort was meritorious, for it removed one of the great bug-bears of modern housekeeping, metal polishing. This troublesome household task is necessary even when chromium-plated curbs are utilised. The examples we have seen were perhaps not sufficiently colourful for the market, as they were mostly available in the dull brown mottled phenol-formaldehyde resin. A brilliant black screen was much more effective and more successful.

Another very interesting and important application of moulded phenolic and urea resins is for the casing or surround of electric heaters, particularly the modern convection heaters of E. K. Cole Ltd. and the G.E.C. The advantages which can be claimed for plastics are as follows :

1. Permanent colour effects.
2. Lightness in weight, which renders the fire more portable and generally convenient.
3. Efficient insulation and easier handling for portable fires.
4. Freedom of design facilitated by the moulding process.
5. Ease of cleaning, as a brisk rub down with a clean cloth restores the original high polish.

The moulding for the Thermovent convection heater is one of the largest in the country and the 2-kilowatt type measures 23½ in. by 16¼ in. by 8½ in.

Mouldings are not suitable for applications where any great strain is placed on the moulded surface, such as the seat of a chair. There seems no reason, however, why many smaller items of furniture should not be built up of moulded units and it is rather strange that moulded panels have not yet been developed for constructing sectional bookcases.

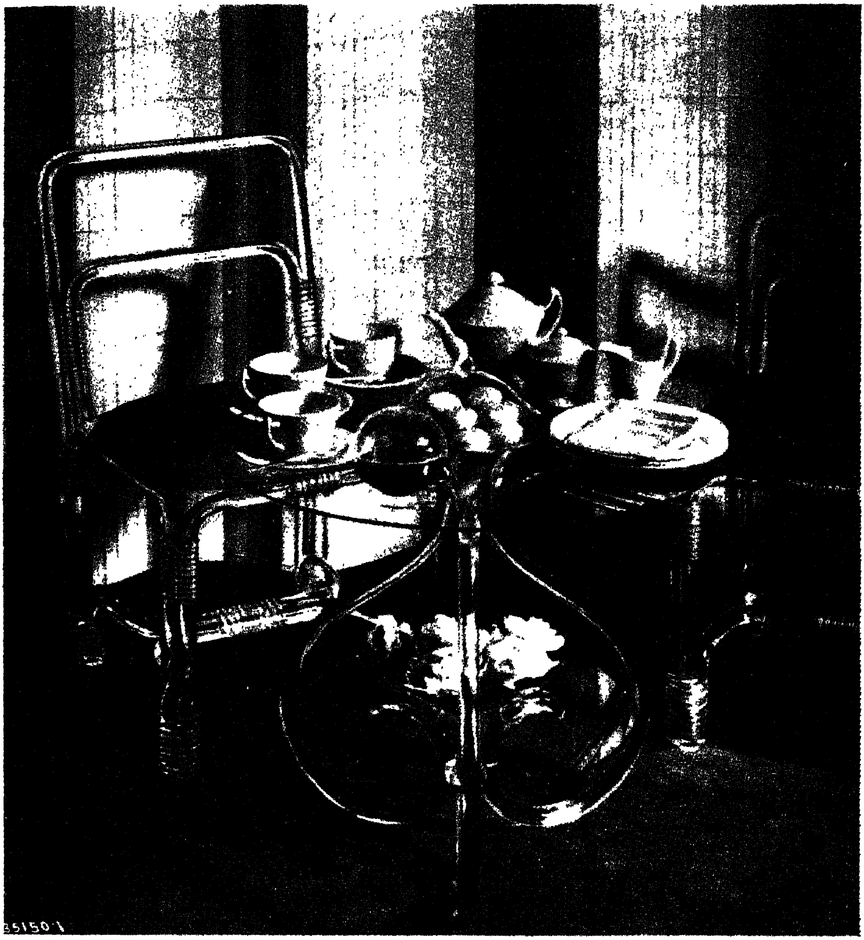

Table and chairs manufactured from Lucite (acrylic cast resin made by E. I. Du Pont de Nemours).

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In the Fourth Annual *Modern Plastics* Competition, recently held by *Modern Plastics* Magazine, the conference-table entry of the Shaw-Walker Co., Muskegon, Mich., U.S.A., won an award in the Decorative Moulded Section. The interesting fact about this table is that it has a protective moulded edge around the periphery of the top where tables for any purpose get their greatest wear. Fabrication of the table was accomplished by attaching short moulded plastic sections combined to form a continuous protection around the top edge. The moulding was cleverly engineered so that the plastic segments fit closely in assembly and no joints or separations appear. It will be realised that such construction permits tops of any size to be made from the same dies and ensures permanence of finish at the most vulnerable points.

## Extruded Strips for Edging Tables.

Of considerable interest to cabinet makers is the use of extruded phenol-formaldehyde strip material for edging tables and other items of furniture. Apart from the decorative value of this strip, which takes the place of wooden mouldings, it has good wearing properties and resists scratching, abrasion and cigarette ends far better than wood. It can be attached to the wooden surface with a suitable adhesive.

One of the most interesting of recent applications of extruded phenolic mouldings is for curtain railing or runways and examples of these were shown for the first time at the 1938 Building Exhibition. The plastic railing has the great advantage over metal of being non-corrodible and exceptionally easy and noiseless in working. The extruded strips can be inserted in grooves in the woodwork and so rendered invisible ; an improvement over the usual rather unsightly metal strip which, incidentally, needs a pelmet to hide it from view.

## Decorative Veneers.

These are available from about $\frac{3}{64}$ in. in sizes about 6 ft. by 3 ft. and they are glued to the three-plywood base with casein glue in large daylight presses at about 50 lb. per sq. in. for twelve hours without heat. In principle this is the method, although naturally it can be adapted in several ways to meet special requirements. The best results are obtained by loading the press so that the out-

side surfaces of the veneers face one another, being separated only by sheets of tissue paper to prevent scratching.

The most popular veneer is the ordinary black highly polished sheet used for bar counters, but many highly decorative sheets are available. The light-coloured veneers have a top surface of urea impregnated paper or fabric and the paper may be a clever reproduction of natural wood, marble, metal or indeed any other material. The urea resin does not result in staining or disfiguration of the original, only a slight darkening of the colour which is often an enrichment and therefore not displeasing. Photographs and original paintings may be impregnated and form the top surface of the sheet. Veneers of natural wood or woven veneers in contrasting colours can also be employed.

In addition, coloured inlays are possible and these are made by cutting a design of one colour out of impregnated but uncured sheets and laying it over a background of another colour. Metal foil may also be utilised to provide special effects. When the assembled sheet is subjected to heat and pressure a complete unified veneer is obtained. Some veneers include a sheet of aluminium foil or other metal immediately underneath the top or decorative surface which renders the veneer heat resisting by conducting away the heat formed by a hot vessel or burning cigarette end.

**Door Furniture.**

Door-handles, knobs, finger-plates, etc. of plastic origin are now in fairly common use. They are either moulded of phenol-formaldehyde resin, injection moulded of cellulose acetate on die-castings or fabricated of cast resin. The first-named are naturally the cheapest, but the colours available are restricted to shades of brown and black. Provided good quality cotton-filled moulding powder is utilised, this being the grade recommended where the moulding has to withstand vibration and shock, and the moulding process properly carried out, then there is no reason why the finished articles should not give satisfaction. It is a fact, however, that a good deal of very shoddy material has been used by speculative builders during recent years and, in consequence, public reaction to plastics for the purpose is not too favourable. Metal-reinforced phenol and urea mouldings, such as are now widely used on board passenger ships, are very much more suitable than

straight mouldings, but they are, of course, a good deal more expensive. There seems to be a great future for cellulose acetate, used either alone or, preferably, injected on metal die-castings so as to give the desired rigidity and strength to the finished item. The advantages which can justly be claimed for this method are: maximum strength, wide colour range and excellent finish. Cellulose acetate is available in dozens of different colours, apart from white and black, and all these are permanent and cannot be scratched off in the same way as the lacquered or painted coatings on metal. Although acetate has a much softer surface than phenol mouldings, it is nevertheless very tough (see physical properties in earlier chapter) and can be relied upon to stand up to the abrasive effects of continuous service without showing evidence of wear. Instead of actually moulding the acetate round a solid metal core, it is possible to wrap acetate sheet round the metal or extrude acetate tubing over a smaller metal tube. This method is only suitable for certain very simple shapes, but for door-handles of commercial buildings use is made of the process. The acetate covering varies in thickness from $\frac{10}{1000}$ in. to $\frac{85}{1000}$ in. and the diameter of the tube from $\frac{1}{2}$ in. to $2\frac{1}{2}$ in. rising by $\frac{1}{8}$ in. Extruded acetate tubing is extensively used for the handrails of commercial vehicles, especially the bulkhead handrails of trolley-buses which have to be tested to 10,000 volts.

Whilst door furniture fabricated of cast resin is very attractive and distinctive, it is also somewhat expensive in comparison with moulded handles, finger-plates, etc. Many pieces are cut from standard rods and tubes and finished by simple methods akin to wood or metal working. Threading and tapping is quite simple as standard dies and taps can be used. In the case of very small holes, machine screws may be run into the holes and allowed to cut their own threads. Self-tapping screws are also extensively employed.

### Synthetic Resin Adhesives for the Plywood and Furniture Manufacturer.

During recent years various types of synthetic resin glues, particularly Tego Film, Plybond, Beetle Cement and Aerolite, have been made available for the plywood and furniture manufacturer. The first two products are in the form of dry sheets of varying thickness made by impregnating absorbent paper with a

solvent solution of phenol-formaldehyde resin, followed by drying. This form of adhesive is supplied in rolls and used as a dry film. To develop and utilise the high bonding or adhesive properties of the resin it requires both heat and pressure. It can be realised that the use of a dry film adhesive is a very great convenience for the manufacturer, as it enables him to eliminate waste and exercise a very careful control over work in process.

Beetle Cement and Aerolite are the best-known liquid glues and consist of thick, syrupy solutions of urea-formaldehyde resin which do not require heat to complete polymerisation as use is made of separate hardening solutions. A hot hardener can, however, be supplied for use by the hot process in heated presses. Urea liquid glues must be used before a certain date specified by the manufacturer on the containers.

Advantages which can be claimed for synthetic resin glues are as follows :

1. High strength.
2. Water resistance.
3. Fungi resistance.
4. Rapid setting.
5. Economy in use.
6. Non-staining.

**Dry Film Glues in Plywood Manufacture.**

Successful bonding of the veneers, using one of the well-known dry film adhesives, depends on two important factors :

1. Moisture content of approximately 9 per cent.
2. Careful control of temperature, pressure and time in the presses.

Moisture content of the veneers has a great effect on the strength of the finished wood, either too little or too much moisture resulting in a poor shear value for the finished plywood. It has been said that synthetic glues give a rather brittle joint, but if working conditions are carefully watched, there is no reason why this should be the case ; indeed, manufacturers of the various glues claim that flexibility of the bonded wood is one of the main characteristics of modern materials.

Broadly speaking, the method of plywood manufacture, whereby use is made of the dry glue film, is as follows : First of all the veneers are conditioned so that they contain the optimum percentage of moisture. The sheets of glue film are then cut to

the desired shape and placed between the veneers, using one film of appropriate thickness for each particular type and grade of wood. The assembled veneers and adhesive are next placed in a daylight press and packed between thin aluminium sheets. The press is closed and pressure and heat applied to ensure firm bonding of the veneers. Pressure varies with different types of wood, but is generally between 120 and 300 lb. per sq. in., temperature 280° F. to 300° F. This is the range recommended by the manufacturers of British Tego Film. The following pressures are recommended for users of Tego Film:

120–140 lb. per sq. in. for pine, Douglas fir, spruce or other coniferous woods in all-veneer construction.

140–150 lb. per sq. in. for poplar, basswood, cotton wood, alder and similar low-density woods for rotary core stock or soft wood cores.

150–200 lb. per sq. in. for gum, oak and high-density woods for core stock.

200–300 lb. per sq. in. when gluing thin panel stock of all hard or deciduous woods, such as 3- or 5-ply hard maple, birch, beech or oak.

Time in veneer press varies with different thicknesses of wood from 5 to 20 minutes. Bonded sheets require standing to allow for cooling and normal absorption of water before working.

Impregnated and compressed woods are made in a similar manner to plywood, only the pressures are, of course, very much greater. The method of manufacture is outlined in an earlier chapter. These compound woods do not find many applications in the furniture industry on account of their weight, hardness and comparative difficulty of working. It is, however, noteworthy that carved and plain panels made of partly or lightly impregnated beech veneers are used on the Continent for decorative purposes and such panelling is installed on the Dutch railways.

Apart from the use of dry resin films, alcoholic solutions of phenol-formaldehyde resin are sometimes utilised for very much the same purpose. The dry film is, however, to be preferred on account of the simplicity of operation and the ease with which it can be standardised. This question of standardisation is of the utmost importance to the manufacturer handling large quantities of plywood. He must be assured that there is no variation in the

shearing strength of different consignments of the same grade. Prejudice which seems to have arisen in some circles against the use of synthetic glues is mainly due either to lack of knowledge or insufficient experience.

**Urea Cold Glues.**

It is claimed that the joint given by these glues is so strong that when subjected to severe strain the wood itself splits before the actual bond. Another very important claim put in by the manufacturers is that long re-drying is unnecessary after gluing, as little more than one-sixth the amount of water is used with the synthetic glue than is the case with ordinary cold glues of animal or vegetable origin. Moisture content of the wood before gluing need not be as rigidly controlled as is necessary when using other types of synthetic and skin glues. The manufacturers of Beetle Cement state that the wood can contain 0–25 per cent. of moisture, an extremely wide range, without deleterious effect on the strength or permanence of the joint. It is, however, necessary to dry the surface of the wood when its moisture content reaches the maximum amount specified.

The method recommended for cold gluing is as follows: The cold hardener, using either the rapid or slow working solution according to requirements, is applied thinly by means of a rubber sponge or a soft brush to one only of the surfaces to be glued. About 1 lb. per 100 sq. ft. should be applied. The surfaces must then be dried and the sheets or pieces can be stored for several days until work is ready for gluing. Minimum drying time is thirty minutes, but it is possible to carry out gluing after only fifteen minutes, provided proper precautions are taken; using hardened and glued surfaces whilst still in the tacky state. Before glue is applied, any dirt which may have accumulated has to be removed with a soft brush, but the treated surface must not be rubbed down with sandpaper or worked in any way. The glue is applied to one of the surfaces only in the form of a very thin coating, using approximately 2½–3 lb. for each 100 sq. ft. Too much glue is almost as bad as too little and 5 lb. or more per 100 sq. ft. will definitely result in delayed setting. Fifteen minutes after gluing the work is ready for the press. Pressing of the two treated surfaces is carried out in ordinary hydraulic or screw presses at room temperatures 10–20° C., making certain

that the surfaces are in intimate contact. Pressure, which is variable, can be maintained for varying periods of time, ranging from about three and a half hours to twelve hours or more. It is necessary to apply pressure within 15 minutes when once the press is loaded.

The above process can be varied considerably according to the type of hardener used, that is the quick or slow type, how it is applied and the method of using the glue. A number of alternative processes of application are given by the manufacturer to meet the special requirements of cabinet makers.

**Hot Process.**

This is the method recommended for joints that have to be highly resistant to water, both hot and cold. Two different hardeners are available, one for waterproof joints and the other for joints which have to stand up to the effect of boiling water. The former is a liquid and the latter a powder. Unlike the cold urea glues, for hot pressing the hardener must be mixed with the glue before application to the wood surface. The mixture remains usable for twenty-four to thirty hours when stored at normal room temperature.

The mixture of synthetic glue and hardener (the quantities vary with the two different hardeners) is applied very thinly to the wood surfaces, using 2 to 2 lb. 10 oz. per 100 sq. ft. Ordinary glue spreaders can be employed. The usual roughening is unnecessary, sanding being sufficient to form a good key. Pressure is carried out in heated presses, 90–100° C., at a pressure of 28 lb. per sq. in. or more, according to requirements. Time of pressing depends on the thickness of wood to be joined. Minimum times are five minutes when using the liquid hardener and eight minutes with the powder hardener, plus one minute for each millimetre of wood, calculated to the deepest joint from the surface.

If desired, the glue mixture may be thinned down with a little water, not more than 10 per cent., or with various thickeners and extenders, such as rye flour. Methods of working are adaptable ; temperature of pressing can be increased up to 170° C., the actual time, of course, being reduced in proportion.

CHAPTER XV

# PACKAGING AND DISPLAY

## PACKAGING

During the last five years a great deal of interest has been shown in the use of plastic materials for packaging, the most important development being the utilisation of transparent cellulose film for protective packaging and overwraps. In the food industry, particularly in the case of perishables that are handled many times on the way from producer to consumer, transparent cellulose wraps are being used to an increasing extent as it is realised that, apart from the hygienic advantages of the protective envelope, it greatly enhances the sales appeal of the commodity. In America, thanks to the strenuous efforts of E. I. du Pont de Nemours & Co., Inc., " Cellophane " has, at 35 cents a pound in comparison with $2.65 a pound in 1925, been widely adopted by the food industry. Thus bread, cake, meats, poultry, cheese, butter, vegetables, etc., are now " Cellophane " wrapped, as well as a very large number of toilet, pharmaceutical and luxury items. In this country the largest single outlet of cellulose wrapping is in the tobacco industry for wrapping packets of cigarettes, but the main sales are in the food industry for wrapping sweets and confectionery products. So far very little " Cellophane " has been used in this country for wrapping bread, primarily on account of the difference in price between it and waxed paper. Increased amounts of cellulose wrapping material is being used in the toilet, pharmaceutical and fancy-goods trade in this country.

### Transparent Cellulose Film.

The modern cellulose film, a development of the original regenerated cellulose of Cross and Bevan in 1892, is made from sheets of pure sprucewood pulp which are changed into alkali cellulose. This is shredded and converted into cellulose xanthate by means

of carbon disulphide. The xanthate is dissolved in caustic soda solution and allowed to ripen under carefully controlled conditions before it goes to a casting machine. Here the liquid becomes a solid through the action of an acid coagulating bath. It is drawn through a number of other chemical solutions and at every stage of the processing it becomes progressively purer, more transparent, tougher and more pliable. Eventually the foil is wound on a core and prepared for shipment. Apart from wound cellulose foil, sheets are also available. The best-known transparent cellulose wrapping material in this country is "Cellophane" cellulose film, manufactured by British Cellophane Ltd.

Ordinary cellulose wrapping is not moisture proof and is therefore unsuitable for wrapping many food products which must not be allowed to lose their moisture and dry out. A moisture-proof variety is, however, available for packaging food products, etc. It is made by coating the plain or normal cellulose sheet with a special lacquer or varnish, which renders the cellulose impervious to moisture, also toxic gases. Another grade of cellulose foil is coated with a very thin layer of paraffin wax and is known as "self-sealing" or "heat sealing" as it does not require any adhesive, only momentarily application of heat (approx. 130° C.) followed by slight pressure. Spirit gum adhesives are recommended for use with cellulose film, and manufacturers usually specify special recipes for their own products.

Usual thickness of film for food and miscellaneous packaging is $\frac{1}{1000}$ to $\frac{2}{1000}$ in., the thickness for any particular application depending on the type of pack handled. Rigid packs usually require a thinner sheet than soft ones, which may be pulled out of shape by the stretching of the foil.

Cellulose foil can easily be adapted to mass-production packaging methods, both hand and mechanical. Modern American bread-wrapping machines operate at a speed of sixty loaves per minute, using either wax or cellulose wrapping. Provided proper adjustment is made, there need be no difference in the speed of automatic wrapping machines when cellulose film is substituted for ordinary waxed paper.

Apart from transparent cellulose film, various coloured foils are available, although, naturally, the transparent variety is the most popular. Printing in one or more colours is possible and practical, and the sheet may also be decorated by the embossing

process. Gaily coloured cellulose tapes can be used to improve the sales appeal of the pack and self-adhesive coloured tapes are available for sealing packages.

The ability of the moisture-proof cellulose film to resist the entry of poisonous gases assumes considerable importance in war-time and the Authorities recommend the use of such materials for protecting many different types of foodstuffs liable to absorb or be directly contaminated by toxic gases.

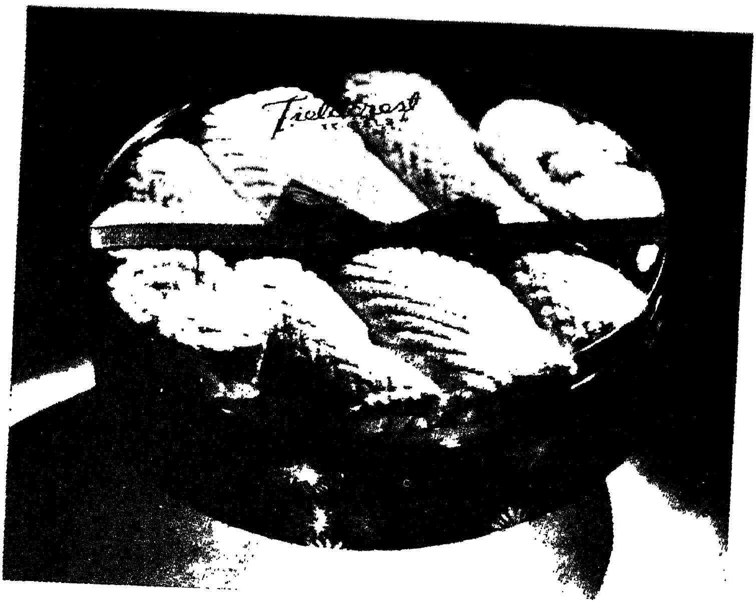
For applications requiring a more rigid pack than is possible by cellulose film, use is made of thin cellulose acetate foil $\frac{5}{1000}$ in. thick.

**Transparent Rubber Wrapping Material.**

During the last two years rubber halides, particularly " Pliofilm " (rubber hydrochloride) made by the Goodyear Tyre Company, U.S.A., have been used in place of cellulose products. Quite briefly, Pliofilm is manufactured by a process developed from the first experiments of Bradley & McGavack in 1923 (U.S.P. 1519509, 1923), who obtained a transparent form of rubber by merely passing hydrogen chloride through a benzene solution of rubber.

Pliofilm differs in many important ways from cellulose film, probably the most important difference being its greater strength and elasticity and inherent waterproof and moisture-proof characteristics (as it does not rely on the waterproof qualities of a lacquer coating). Unlike most rubber compounds, this commercial hydrochloride is not only completely odourless, but is unaffected by mineral and vegetable oils ; indeed, it is used by manufacturers in the States for packing lubricating oils. It is also resistant to weak acids, alkalies, mould and insects.

Pliofilm is made in five different thicknesses, varying from $\frac{1}{1000}$ in. to $\frac{2}{1000}$ in., and is available in rolls and sheets. It is very suitable for all applications which require a moisture-vapour-proof or waterproof protective wrap. An important practical point is that bag making, laminating, printing, sealing and, in fact, all the usual handling processes do not in any way adversely affect the high moisture-resisting properties of the material. It can be readily sealed or welded by the direct application of heat alone or with a combination of heat and solvent. According to data supplied by the Goodyear Tyre & Rubber Company, for sealing with



Three attractive transparent acetate packages.

*Facing p.* 201.]

heat the most effective temperature is usually about 115° C., although it is pointed out that the sealing temperature will naturally vary with pressure and time of contact. By employing a solvent such as toluol in conjunction with heat, this sealing temperature can be reduced by from 30 to 35° C. The sealed joints can be made relatively weak or strong, as desired, by adjusting the sealing temperature.

Dimensional stability of Pliofilm is extremely good. There is no dimensional change in the humidity range of 15 per cent. to 90 per cent. It does not, therefore, wrinkle or crease in the same way as cellulose materials. Elasticity is stated to be twice that of cellulose. Coloured varieties of Pliofilm are available, also coloured tapes (adhesive or otherwise) and the sheet may be printed with suitable inks without difficulty. Apart from the use of Pliofilm for packing solid products, it is also suitable for all kinds of syrupy and oily goods ard is, in fact, used in America instead of cans for packing fruits in syrup for quick sale. It is primarily in the food industry that the moisture-proof qualities of this rubber derivative are likely to be most exploit, although it is worth noting that a large blanket manufacturer in the U.S.A. is using Pliofilm to keep his goods moisture- and moth-proof.

## Cellulose Acetate Boxes.

Acetate sheets in various gauges, from $\frac{3}{1000}$ in. upwards to $\frac{3}{4}$ in. or even thicker when specified, are used for making transparent boxes. Standard sheets vary somewhat in size, but are usually about 50 × 20 in., which is a very useful size for box-making. Waste from box-making can usually be returned to the manufacturer for re-processing. Various surfaces are available, including matt, rough matt, high polish, tissue paper, knife lines, etc. Sheets can be cemented together to make strong joints by use of a simple mixture made up of

| | |
|---|---|
| Benzene . . . . . . . . | 200 c.c. |
| Acetone . . . . . . . . | 1 gallon |

(A little clean acetate scrap 5–10 per cent. may be added, if desired.)

Thin sheets of acetate can be cut easily with a hand guillotine or scissors, folded and generally worked without difficulty.

Acetate boxes are now being used for packing beauty prepara-

tions of various kinds, also luxury items in various other trades. It is interesting to note that a growing use is being made of extruded acetate tube instead of glass vials for packing pharmaceutical products.

Advantages which can be claimed for acetate containers over glass are, first of all lower weight, the specific gravity of cellulose acetate is 1·29 compared with 2·5 for glass; greater strength, acetate has a tensile strength of 4,500–7,500 lb. per sq. in., whereas glass varies between 2,413 and 6,000. In addition, acetate possesses a considerably greater elasticity, flexibility and resistance to shock than ordinary crown or flint glass. Acetate is in all ways an excellent material for packs to contain dry goods having a neutral reaction as acetate gradually decomposes in the presence of weak alkalis and acids. It is not recommended for aqueous products as its moisture-absorption figure is rather high, average absorption being about 2 per cent. in twenty-four hours. Stability of acetate containers is good as the material is unaffected by light and, provided the containers are stored in a dry place, dimensional stability is satisfactory.

An increasing number of acetate caps and closures are being moulded by the injection process, and they are recommended for tubes containing peroxide dental pastes. Free peroxide is liable to attack phenol-formaldehyde mouldings containing even traces of free phenol, and when this happens the surface of the toothpaste is slightly discoloured and contaminated.

So far, little use has been made either of polystyrol or methyl methacrylate injection mouldings on account of their high cost. It is, however, not unlikely that polystyrol may find worthwhile applications in the packaging field for closures, particularly for products containing alcohol, which has no solvent or swelling action on this resin. Although at present it is more costly than acetate, it has a lower specific weight, coupled with greater rigidity, so that thinner sections can be used. These are considerations which are liable to be overlooked by manufacturers who simply consider the price per pound of the two moulding compounds.

### Compression Moulded Packs.

Both phenol-formaldehyde and urea-formaldehyde resins are now being fairly extensively employed for moulding bottle caps, jar closures and various novelty packs, particularly for perfumery

and cosmetic goods. Whilst caps of the Bakelite type are quite suitable for sealing containers holding solvents, oily and aqueous preparations, urea mouldings, being liable to swell when in contact with water, are not suitable for use with aqueous products. Urea mouldings are, however, completely odourless, which is a great advantage for certain types of goods.

High tool cost has generally been the main obstacle to the more general adoption of thermo-setting resins for packaging purposes. Modern automatic machines, use of multi-cavity moulds, better quality steel and improved designs are, however, reducing tool costs. The latest automatic presses are capable of enormous outputs. The Stokes 15-ton capacity machine can turn out 13,440 mouldings per normal working week and is equipped with many refinements, such as double or triple feed and measuring devices for feeding materials of differing type or colour or different grades of powder into one or more of three moulds mounted on the same platen, also unscrewing devices for removing mouldings with threads and ejecting them automatically.

In the case of caps and closures, as well as many simple types of containers, stock moulds are occasionally available which reduce the cost very considerably and enable small users to obtain supplies at highly competitive prices. The author is of the opinion, however, that whilst the practice of offering the use of stock moulds for only a percentage of original tool costs may lead to immediate business, in the long run it does not pay as it encourages price cutting and leads to disillusionment on the part of customers. Manufacturers who have had the advantage of stock moulds usually find it difficult to account for the exorbitant cost of new moulds rendered necessary by alterations in the original design.

Mouldings may be decorated by means of metal inserts, transfers and sprayed lacquers. In addition, boxes of various kinds may be provided with a number of different spring hingeing devices which are definite improvements on the old piano-hinge type. Another innovation is the use of units made up of two or more mouldings, the base perhaps being moulded of black or dark coloured phenolic resin and the top portion of white, ivory or light coloured urea resin. Some of the latest phenolic mouldings for the cosmetic trade are decorated with small cellulose acetate mouldings stuck on to the surface of the phenolic plastic by means of a special cement.

Apart from the use of thermo-setting plastics for straightforward containers and novelty packs, they find a ready sale as re-use containers holding seasonable gifts, such as handkerchiefs, cigarettes, perfumes, etc. Plastics can be made to combine attractiveness and utility with real economy, provided always that sufficient containers are made to reduce tool costs to a safe minimum per moulding.

The best caps, closures and applicators of various kinds are moulded of good-quality phenol-formaldehyde resin free from cresol. Use of low-grade resins, or resins adulterated with ground flash, etc., results in a high percentage of rejects and inherently weak mouldings. Hurried workmanship, which generally means insufficient and incomplete curing, frequently produces mouldings containing traces of free phenol or cresol. The presence of even a suspicion of these chemicals causes the mouldings to have a strong disinfectant odour and is liable to contaminate delicate products, particularly fats or fatty preparations, such as face creams, etc., which are very absorbent.

Those manufacturers who have closely studied market tendencies believe that public reaction to plastics is favourable, provided the novelty angle is stressed and the tell-tale mottle effect, so reminiscent of those early ash-trays, is avoided. There is no doubt that plastics can materially increase the sales appeal of a product if the pack is well designed, not only from the manufacturer's own standpoint as regards exploitation of his product, but also from the viewpoint of the plastic material. The services of designers who have specialised in plastics should be obtained in preference to those without any actual experience of these materials.

Important advantages which are claimed for moulded packs may be briefly summarised as follows :

1. Economy for large outputs.
2. Improved appearance and therefore greater sales appeal.
3. Permanent colour effects, especially in the case of urea resins.
4. Light weight and therefore lower freightage charges, as well as added convenience in handling.
5. Stream-lined designs.

PLASTICS AVAILABLE FOR PACKAGING PURPOSES AND THEIR PRINCIPAL APPLICATIONS

| Name of Packaging Medium. | Types of Material Available. | Main Uses. |
|---|---|---|
| Transparent cellulose foil "Cellophane" | Sheets 1 thou. in. to 2 thou. in. generally used | Protective wraps for food, tobacco, cosmetic and toilet lines. For food and tobacco the moisture-proof grade is used, whilst for overwraps the ordinary foil is preferred. Foil can, in paraffin-wax-coated grade, be heat sealed, otherwise sealed by means of spirit gums. |
| Rubber hydrochloride Pliofilm | Sheets 1 to 2½ thou. in. | Protective wraps for food, woollens, textiles; indeed, any products which require moisture and waterproof wrappings. This foil is particularly suitable for awkwardly shaped packs which are liable to burst ordinary cellulose. Heat sealed, sealed with adhesives, or both methods can be used. |
| Cellulose acetate, known under half a dozen different trade names | Sheets from 3 thou. in., tubes and rods, also granular powder for injection moulding | Built-up boxes with or without rigid cardboard bases, also various kinds of display cases for beauty preparations. Sealed with cement. Small diameter tubes for dry pharmaceutical containers, injection moulded caps and small vials for drugs. Apart from transparent grade, wide range of colours available. |
| Polystyrol, known under three or more different trade names | Granular powder for injection and compression moulding, usually the latter | Caps and closures for sealing special products, particularly alcoholic solutions liable to attack other types of plastics. Transparent and coloured powders may be obtained. |
| Phenol-formaldehyde resins, known under several trade names | Granular powder for compression moulding | Caps and closures suitable for practically all liquid and solid goods, except perfumes. Novelty and gift containers for toilet lines, such as shaving soaps, also certain pharmaceutical products. Haberdashery and fancy goods. Black and dark colours only. |
| Urea-formaldehyde resins, known under three or more trade names | Granular powder paper or wood filled for compression moulding | Caps and closures for solids and pastes, but not recommended for aqueous solutions. Various novelty and gift containers for miscellaneous products. Can be used in conjunction with phenol-formaldehyde resins. Urea mouldings are completely odourless. White and wide range of light colours available in both paper- or wood-filled resin. Best finish obtainable by use of paper-filled grade. |

## SIGNS AND DISPLAY ITEMS

The most popular and suitable materials for signs are cellulose acetate sheet, cast resin and methyl-methacrylate resin. Display items are also fabricated of these materials and many of the smaller items are moulded of phenol-formaldehyde and urea resins.

### Cellulose Acetate Signs.

Cellulose acetate sheets are available from $\frac{3}{1000}$ in., but the most useful grade for the signmaker is about $\frac{50}{1000}$ in. to $\frac{55}{1000}$ in., although thinner material may be used for smaller signs. No hard-and-fast rule can, however, be laid down and the thickness chosen must naturally be influenced by the degree of rigidity required. The simplest method of fabricating hollow signs is as follows. Sheets of acetate are first cut to the required size by means of a pair of scissors for sheets up to $\frac{40}{1000}$ in. or a hand guillotine for sheets up to $\frac{80}{1000}$ in. The sheets are then softened, either by stacking in special gas-heated ovens maintained at approx. 50–60° C., or soaking in boiling or hot water (90° C.) for a minute or so. The former method is to be preferred as immersion in hot water causes a small percentage of moisture to be absorbed and this may lead to a slight swelling or distortion of the formed or moulded sheet when it dries out. The softened sheets of acetate can then be placed between wooden formers and pressed into shape by hand or mechanical pressure. Flash may be removed by scraping with a sharp knife, followed by a simple smoothing action with fine emery or sandpaper. Stripped of all technicalities, the above is, in the main, the method generally adopted. Sheets or mouldings may be joined together with a solvent solution made up of 1 part benzene and 2½ parts acetone. If desired, ¼ part of clean acetate scrap can be added to this to make a cement with a certain amount of body in it. Cemented parts must be kept in close contact under light pressure until properly annealed. Small signs or parts of signs can be made stamped out or they may be made by blowing air between two pieces of acetate sheet previously heated and placed between top and bottom dies.

Apart from normal grades of acetate, transparent and translucent coloured, fluorescent sheeting is now being used by fabri-

cators of modern signs. The fluorescent acetate is ordinary acetate impregnated with certain dyes which glow when irradiated by ultra-violet light. Sensational effects can be obtained by the use of this material as it enables fabricators to take full advantage of the remarkable edge lighting properties of the plastic. Thus, when sheets are carved or simply scratched with simple tools, the incisions or scratches show up as brilliant etchings against a weak glow of colour from the main area of the fluorescent acetate.

Yet another form of acetate is now being exploited; this is the luminous form. In this case the acetate is impregnated with luminous pigments, particularly calcium, barium and strontium sulphides. Luminosity varies a good deal with different grades of pigments, but when irradiated for an hour or so the best grade of luminous acetate will show up in total darkness for one to four hours. Life of the luminous material is uncertain as the sulphides are continually breaking down due to evolution of hydrogen sulphide. There seems no reason why this material should not be utilised for small window signs making use of an intermittent internal lighting which for a certain period would transmit light in the normal way and then for perhaps a longer period give off a ghostly luminosity when the electric light was switched off.

**Cellulose Acetate Display Items.**

Counter and window displays fabricated of acetate sheet are now in fairly common use. Usually these take the form either of formed or moulded items such as the familiar display for silk stockings, or simple cut-outs from sheet material about $\frac{1}{16}$ in. to $\frac{1}{8}$ in. thick. In the latter case good use is made of the edge lighting characteristics of the plastic which may be accentuated by incorporating a trace of fluorescent dye in the sheet. It is now possible to reproduce colour photographs on sheets of acetate and these may be utilised as transparencies for all kinds of advertising displays. Thus the new Kelvinator unit for frosted foods is provided with a display stand containing five acetate transparencies showing fruits and vegetables in all their rich natural colours. The transparencies are shown up by means of evenly diffused transmitted light. Another method of decorating acetate sheet is by means of oil paints, special translucent inks, poster colours, etc. These adhere well to cleaned material and well-

planned designs show up to advantage. Solid acetate sheets can be easily sawn, drilled, threaded, routed and turned.

**Cast Resin for Signs and Display Items.**

Cast resin is available in sheets, slabs, rods and tubes. It is widely used in America for solid and hollow signs, an interesting outlet being signs for commercial vehicles cut out of cast resin sheet material. A number of small signs for shop fronts and commercial buildings, also ocean liners, etc., are made of transparent cast resin letters set into hardwood. This plastic can be fabricated in very much the same way as wood or soft metal, such as brass. It can be sawn, turned, engraved, drilled, tapped, embossed, routed, etc. The material will take a high and lasting polish when it is properly finished. Method usually recommended is to sand lightly, continue rubbing down with pumice and water and finally polish on a muslin wheel.

The fact that cast resin is available in a transparent form as well as in a wide range of colours renders it particularly adaptable and suitable for sign-making and display purposes. Although a number of items can be successfully fabricated from the sheet, rod or tube, the more elaborate three-dimensional and highly finished pieces are cast from the liquid resin in lead moulds and afterwards hardened in the moulds by heating under carefully controlled conditions in special ovens. Cast resin lends itself to forming or bending provided it is first heated to 180° F. by immersion in hot water or by means of hot plates. After forming it must be cooled in cold water immediately.

Solid rods and tubes of coloured cast resin can be utilised for making display stands for shop windows and they are more attractive than glass and far less fragile. In America use is made of fluorescent cast resin available in an extensive range of solid colours, also a near-transparent variety.

**Acrylic Resins for Signs and Display Items.**

The best-known are, of course, Perspex, Plexiglas, Lucite. Sheets from $\frac{1}{16}$ in. to $1\frac{1}{2}$ in. are available, also rods, bars, tubes from about $\frac{1}{4}$ in. to $2\frac{1}{2}$ in. diameter, either square or round. Original form of this resin is transparent and although it can be dyed, the clear form is generally found the most useful.

Acrylic resins may be drilled, threaded, engraved, routed,

turned and carved with ordinary woodworking tools, provided care is taken to prevent softening of the material through heat set up by friction. Best results obtained by allowing a thin trickle of water to run on to the cutting surface. Final polishing of worked surfaces should be carried out with a good wax car polish.

Rods and tubes of standard acrylic resins can be bent without fear of snapping by first softening by immersion in hot water (90° F.) containing 5 per cent. salt for a few minutes or until workable. Sheets can be shaped in the same way. It is, however, preferable to use wooden formers so as to obtain the more complicated shapes.

Apart from the employment of the well-known forms of acrylic resin for sign and display work, use is made of moulded lenses of this resin, either in the shape of separate entities or pressed bosses forming part of a sheet. In America, reflectors holding six plastic reflectors measuring $1\frac{5}{8}$ in. in diameter and formed of 300 cubes (three on each side) are fitted 3 ft. above the pavement and 8 ft. from the pavement edge. These ingenious lenses or reflectors catch the light from motorists' headlamps and act as directional signs on long stretches of lonely roads. The inventor is Mr. J. C. Stimson of Chicago and the experimental reflectors were originally installed over a 90-mile stretch of road near Detroit. Experimental traffic signs moulded of Diakon, the powdered or moulding form of Perspex, have been produced in this country, but, unfortunately, their high price is against their general adoption by the Ministry of Transport. There seems little doubt, however, that the idea of exploiting the high reflective properties of properly designed lenses for sign-making is one which should be carefully examined. No one yet appears to have tried out the idea of building up signs by merely sprinkling Diakon on to a well-prepared adhesive surface, such as one treated with a special vinyl resin. The Diakon could be spread over the stencilled surface evenly so as to form letters or any desired shapes.

### Moulded Display Items.

Wood-filled phenol-formaldehyde and, to a smaller extent, wood-filled urea-formaldehyde resins are now being used for moulding counter displays, most of which are designed for showing off toilet goods, jewellery, photographic goods and small items. Such mouldings must necessarily be confined to merchandise of

small dimensions owing to the limitation in size of commercial mouldings. Decoration can take the form of transfers, metal inserts and engraved lettering, wiped over with cellulose lacquer ; these are the most common methods of embellishing the plastic surface.

Tool costs are naturally rather heavy, and it may be said that moulded display items only become reasonably economic and practical when required in large numbers, at least 5,000 to 10,000.

The advantages which can be claimed for moulded counter displays are summarised as follows :

1. Permanent colour effects.
2. Lightness in weight.
3. Compactness and modernity of design.
4. Economic in large quantities.

# CHAPTER XVI

## MISCELLANEOUS

IN this chapter it is hoped to describe a number of important and potentially important applications, particularly the use of plastics in the photographic, footwear, food, hardware, optical and sports goods trades. It is, of course, impossible to describe in detail the thousands of small uses now being found for plastics, as they can be seen in almost every phase of modern industrial activity and vary from small and apparently insignificant washers made of laminated sheet to large and complicated moulded housings for Hoover vacuum cleaners and other domestic appliances.

Changes are continually taking place in all industrial fields, many of which are dictated by economics, and these often represent excellent opportunities for plastics. During wartime, when both metal and wood are scarce, manufacturers are forced by circumstances to consider alternative materials. Plastics are to-day recognised as the most practical and economic of these alternative materials, and although the raw material is more expensive than metal or wood, on long runs the finished objects compare very favourably in price. Apart, however, from considerations of cost of production, the use of plastics has many important advantages, many of which can be exploited to the ultimate sales benefit of the product. Take, for instance, the Hoover cleaner. Many of the parts previously fabricated of light alloys are now moulded of phenolic resin, well able to withstand impact and vibration. Use of plastics instead of metal has resulted in greater convenience for the user on account of the increased lightness of the new model, less noise owing to the sound-insulating properties of the material and great safety ensured by the high dielectric strength of the moulded housing. These are a few of the advantages for the consumer, but, in addition, the use of plastics increases production by eliminating several metal-finishing processes and at the same time reduces overheads.

**Plastics in Photography.**

During the last five years plastics have been used to an increasing extent, not only for camera bodies, such as can be seen in the case of such well-known cameras as the Purma, Argus, Karat, etc., but also for a number of photographic accessories, particularly developing tanks and exposure meters, etc. A large amount of celluloid and, to a smaller extent, acetate, or non-flam as it is called, are used for films, both still and cine, also for the aprons of developing tanks. Simple plastic lenses moulded of methyl-methacrylate resin have been made in this country and apparently are quite satisfactory; indeed, they are already finding use in the industry as finder lenses on some cameras.

Provided a good quality shock-resisting phenolic resin is employed for moulding the body of a camera, there is no reason why it should not give perfect satisfaction. The most serious objection to the use of cheap plastic material for this purpose is that it is easily damaged and when cracked or broken it cannot be mended, whereas, of course, both metal and wood can be repaired. Another, although less serious objection, is that if the body of an expensive or even moderately priced camera is moulded of a phenolic resin, the prospective purchaser is apt to think that the plastic is only a cheap substitute for wood or metal. There is still a certain amount of prejudice in the mind of the man in the street towards plastics. For this reason manufacturers are somewhat wary of referring to their mouldings as plastics and they prefer a more ambiguous description, such as "a new non-metallic material possessing special qualities." The moulding itself is often so cleverly camouflaged that it is not readily discernible that it really is of plastic origin. Probably the most effective method of achieving this disguise is to break up the smooth moulded surface by means of a closely engraved design, which may even be an imitation of a characteristic leather grain, such as morocco. Incidentally, this achieves another purpose, as it renders the moulded surface easier to grip when the hand is moist with perspiration.

Turning now from disadvantages to advantages, these may be catalogued as follows:

1. Adaptability of plastics to mass production.
2. Economy in production.

3. Lightness of the moulded body in comparison with metal or even a combination of wood, metal and leather or leather cloth.
4. Warmth of the moulded surface owing to the poor heat-conducting properties of the material.

To the writers the most outstanding advantage of plastics for camera work is that it has rendered possible and practical the stream-lining of the body and so converted an intrinsically ugly and inefficient shape into one which is simple in design, easy to handle and operate and yet possessing the minimum number of sharp angles and narrow curves and the minimum overall dimensions. Generally speaking, the wise use of plastics brings about a definite tidying-up of the design. This does not mean, of course, that all moulded cameras are improvements on similar ones made of standard materials, but it does mean that the use of plastics encourages, by the absolute necessity of efficient moulding technique, a definite stream-lining of the design which can and should make for an improvement in the shape. The German photographic industry has made excellent use of plastics for a wide range of moderately priced cameras and the writers have seen very convincing practical demonstrations of the strength of the phenolic resin used. This is usually a specially compounded fabric-filled material with an exceptionally high impact strength.

Developing tanks and housings for exposure meters are moulded of standard phenolic resins and give perfect satisfaction. A criticism of some moulded developing tanks is that they swell after a year or so of hard service and, in consequence, the lid does not easily fit on to the actual tank. This slight swelling is, of course, due to the absorption of moisture by the resin and the manufacturers state that it can be avoided if the tank is dried thoroughly after use.

Referring briefly to moulded lenses, very little information appears to be available, but according to two representative patents dealing with their manufacture, E.P. 475,035 and E.P. 485,629, the lenses are formed by pressing "plastic glass" (such as Diakon) at a temperature of 100–200° C. between optically polished metal dies, which have been properly corrected. The departure of such lenses, on cooling, from the required spherical

surface is assessed by interferometrical tests and the die is locally polished in accordance with the assessment and used to produce a resultant lens having the required truly spherical shape. Alternatively, an aspherical lens may be moulded by forming the die initially with approximately the required aspherical surface and determining the correction required for local polishing from a preliminary lens in the same manner.

One of the chief teething troubles experienced in the early stages of the production of the moulded lens was the relative softness of the surface, this being considerably less than glass, but the writers understand that the hardness of the finished lens has now been greatly improved by means of a special heat treatment.

**Footwear.**

It is surprising the number of uses now being found for plastics in the shoe trade, some of which are only seasonable novelties of no permanent value, whilst others are of considerable importance. One of the most interesting of recent applications is the moulded Pearsonite heel sold by Pearson Heel Manufacturing Co., St. Louis, Mo., and moulded of Textolite by the Plastics Department of General Electric Co., Pittsfield, Mass. This new type of heel will not split, peel, crack or separate from the shoe and can be attached with the same standard machinery. Because of the flexibility and toughness of the material, nails guided into holes of the interior honeycomb construction become firmly embedded and cannot be pulled out. The bottom of the heel is designed to accommodate a patented Pearson top lift which can be inserted easily. When the lift wears down, it is a simple matter to snap it out and replace it with a new one. This distinctive and yet severely practical plastic non-scuffable heel is available in a wide range of colours to match or contrast with the leather of daytime shoes, while transparent or opaque heels embedded with rhinestones make a glittering ornament for evening slippers. Although, naturally, the Pearsonite heel is more expensive than the standard wooden one, it possesses advantages which render the extra cost fully justified. Incidentally, this moulded heel received one of the principal awards in the Style classification of the Fourth Annual *Modern Plastics* Competition held by *Modern Plastics* magazine in 1939.

Whilst still on the subject of heels, it is, of course, well known

that celluloid is used to provide the wooden heel with a scuffless cover. The celluloid, in the form of a shaped black or coloured sheet 12–15 thou. in., is soaked in methylated spirits until it is thoroughly soft and then forcibly wrapped round the wooden heel or core and allowed to dry. During drying it becomes taut and adheres tenaciously to the wood surface. Celluloid is also used for eyelet holes, lace tips or tags, heel plates and toe puffs. Shoe fillers in paste form also contain plastics and rubber and among the advantages claimed for them over the sheet fillers is the elimination of predetermined sizes and shapes. Manufacturers claim that the new latex cork fillers do not creep, bunch, crumble or permit gutter wells.

Cellulose nitrate and, to a limited extent, the new acrylic resins, are used in the finish of leather and textiles for the shoe industry. According to all reports, aqueous dispersions of acrylic resin have quite a future as leather finishes when the price has been reduced to make the new process competitive.

Shoe ornaments, such as buckles, clasps, etc., are made of casein, cast resin and cellulose acetate. The first-named plastic is the cheapest, but delightful colour effects are possible by the use of the jewel-like cast resin. Cellulose acetate foil may be formed into flower petals and buds and other decorative shapes. An advantage of casein, which is not found with other types of plastics, is that the surface may easily be dyed by means of an aqueous or alcoholic solution of basic and acid colours.

On the operational side of the shoe industry plastics also find several uses. Thus, a new type of shoe pattern made of transparent cellulose acetate edged with metal is now in use in America in place of the opaque fibre pattern. This is called the Da-Lite and is manufactured by J. J. Albrecht & Son, U.S.A. It is claimed that whilst this new transparent pattern fulfils all practical cutting requirements, it enables many worthwhile economies to be made in cutting, as the operator can see exactly what the leather is like under the pattern.

The idea of moulding shoe-lasts of a suitable plastic material has captured the imagination of several workers, but so far the difficulties in producing a material strong enough to stand up to the shocks and vibration of working, to take nails as easily as wooden lasts and yet able to be melted and re-cast when worn out, appear, at present, to be unsurmountable. There is no doubt,

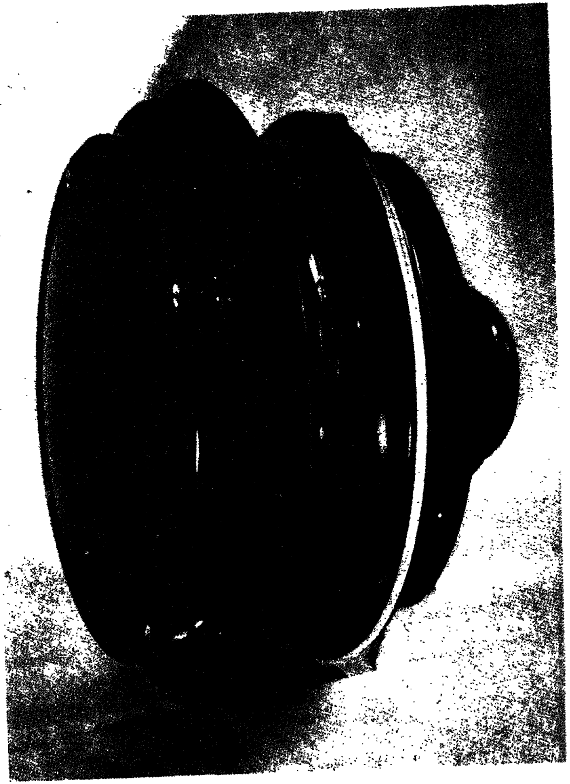
however, that moulded lasts which could be continually re-used would prove a great boon to the industry and, incidentally, save from waste an enormous tonnage of valuable timber. Old wooden lasts are of no use at all, except as fuel.

The plastic suitable for lasts would, obviously, have to be a thermo-plastic and it is possible that one of the new lignin plastics might prove suitable. The writers refer particularly to the lignin-sulphur resins which are thermoplastic and possess reasonably good mechanical properties (degree of elasticity 52,000 kilos. per sq. cm. and modulus of rupture 510–555 kg. per sq. cm. Such products could be made cheaply from wood waste.

**Food Containers.**

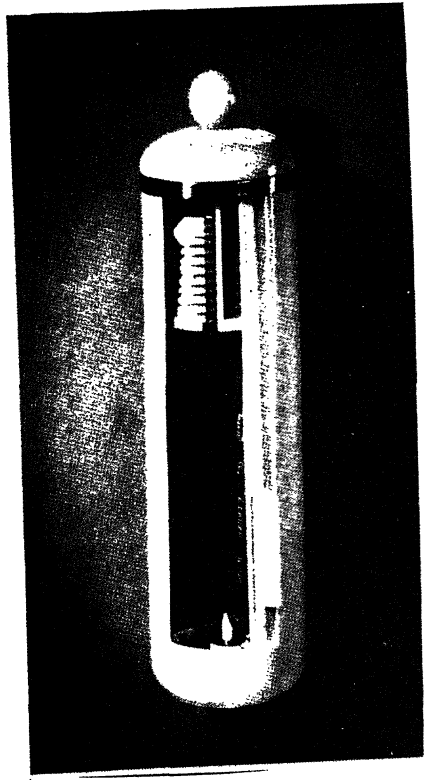
By the use of a special Bakelite varnish which has been polymerised or cured under properly controlled conditions, it is possible to render metal containers and food processing equipment impervious to the corrosive effects of water, solvents and many chemicals used in the food and allied industries. Although it is not possible to give precise details of the method of application, in brief it consists of applying the varnish in solvent solution to the properly prepared metal surface and then baking it to ensure complete polymerisation. To make certain that the predetermined optimum temperature is maintained, the tank or vessel to be treated is well lagged or enclosed in a properly insulated structure, which can be built up on the spot. Several thermo couples are placed in position within the vessel so as to keep a careful check on the temperature of the hot air blown in. The dry coating of fully polymerised resin is only $\frac{3}{1000}$ in. in thickness and adds only $\frac{1}{20}$ oz. per square foot of treated metal.

This protective coating is known as Lithcote, which is the registered trade name of the Lithgow Corporation, Chicago, U.S.A. The process finds its principal applications in the brewing industry and it was originally developed for protecting tank cars designed to carry Californian wine and other alcoholic liquors. In breweries it is used for treating cast-iron sectional storage tanks which have become pitted and scaled. The glass-like surface of the plastic coating is easily kept clean by washing down with boiling water or it may even be sterilised with steam. Sectional mash tuns, fermenters, coolers, filters and storage tanks have also been successfully treated in America. A very interesting applica-



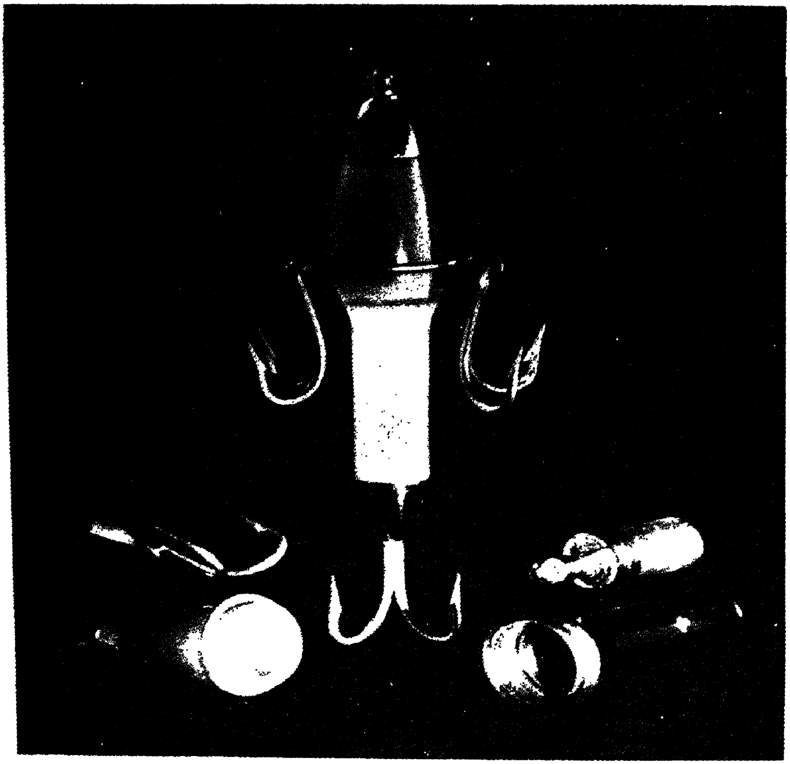
Vent-Axia fan moulded by Thomas de la Rue, Ltd.

All parts except motor are of phenolic resin.



Tooth-brush holder made of Plaskon urea resin moulded by Chicago Molded Products Co., U.S.A.

[Facing p. 216.



ABOVE : " Acrylic " resin dentures.

BELOW : Illuminated fish-lure moulded of " Plastacele " cellulose acetate.

*Facing p.* 217.]

tion of Lithcote is its use for protecting the metal parts of steep tanks used in glucose manufacture. The sulphurous acid, a highly corrosive chemical, has no damaging effect on the plastic film which gives lasting protection to the metal underneath.

Quite briefly it may be said that Lithcote takes the place of an expensive and highly fragile glass lining and achieves the same purpose at very much less cost and without the fear of damage from the results of shock or sudden change in temperature. It can be recommended for protecting all types of food-processing equipment, cookers, boil-off tanks, dairy equipment, milk-holding tanks, whey tanks, evaporators, citrus fruit-juice tanks, fruit-boiling tanks, distillery process and storage equipment.

No figures can be given for the life of the film, but the process has been worked now for several years and the earliest work undertaken is still giving excellent service, which is the highest recommendation possible. The great importance of Lithcote to the food manufacturer is that it enables him to keep in useful commission tanks and processing equipment which, on account of pitting or scaling, would have to be thrown on the scrap-heap in the normal course of business. During wartime, when economy has to be practised, the Lithcote process is, therefore, of the greatest importance.

**Hardware.**

Manufacturers of tools, domestic appliances and all the various small items required by the average housewife are finding that plastics can often be used to great advantage in place of standard materials. Take, for instance, the case of the ordinary saw-handle. This has always been made of hardwood, but quite recently an enterprising American manufacturer decided to break away from tradition and use a moulded acetate handle. The result of this rather startling innovation was highly satisfactory from the sales angle, when buyers realised the advantages of the plastic handle. These can best be summarised as follows:

1. Pleasant warm feel.
2. Non-staining.
3. Increased resistance to shock.

In addition to these advantages, it was reported that retailers were pleased to handle the new line because the introduction of colour

into hand-saws facilitated window and counter displays and so attracted attention. Incidentally, the permanent colour effects obtainable by the use of plastics contribute very appreciably to their favourable reception by the public. Colour is very definitely an important sales factor.

Plastics are now accepted by householders as eminently serviceable and attractive materials and lemon-squeezers, cream-makers and parts of mincing machines, as well as housings, handles, etc., of vacuum cleaners, washers, electric irons, etc., are being moulded of urea or phenolic resins. The former are preferred where the plastic surface has to come in direct contact with food and the latter where high mechanical or dielectric strength are the first essentials. It is encouraging to find that as manufacturers gain more knowledge of the plastics at their disposal, they are using them to greater advantage and so ensuring the maximum serviceability. Cheap and shoddy plastic goods are still on the market, but, happily, they are becoming less common.

**Optical.**

Cellulose acetate is extensively employed in Great Britain for moulding good-quality spectacle frames, although in America opticians prefer celluloid on account of its toughness, flexibility and durability, which qualities are not equalled by any other competitive material. British manufacturers do not make general use of celluloid mainly because of its high inflammability.

A certain number of moulded urea and phenolic frames are used for novelty lines intended for beach wear and the holiday trade generally. The thermo-setting resins are, however, too brittle to be generally serviceable and they are not available in the delicate translucent colours now required.

Methyl-methacrylate and vinyl resins have been used with some success for optical work, particularly for the lenses of industrial eye-shields and for gas-masks in America. They are excellent for this purpose on account of their high-light transmitting properties.

The advantages which are claimed for acetate frames may be summarised as follows:

1. Suitable mechanical properties which ensure good dimensional stability and a reasonably long life for the frames under normal conditions.

2. Good resistance to sweat acids and grease.
3. Low moisture absorption.
4. Lightness in weight and improved general convenience when compared with metal frames.
5. Permanent colours in a wide and attractive range.
6. Non-inflammability and therefore safety of the material.
7. Easy working properties.

Most spectacle-frame manufacturers use cutters and formers for producing frames from acetate sheet material, instead of utilising the injection moulding press, although this machine is now extensively employed for producing small parts. Whilst it is agreed that spectacle frames could be manufactured entirely by means of the injection moulding process, the result would not be comparable in attractiveness or quality to that made by the present methods, which entail a dozen or more separate operations. In the first place it is difficult, if not impossible, to standardise a tortoise-shell configuration by mixing coloured powders, whereas by the present method of sticking together alternate layers of yellow and brown coloured sheets of acetate, cutting the composite block laterally, sticking together again and then cutting transversely, a very close resemblance to genuine tortoise-shell is obtained. It is also claimed that frames made of this laminated material are stronger and better able to resist the stresses and strains of wear than the moulded frame, or indeed one fabricated of the standard sheet. Cheap sun-glasses are now generally made on injection moulding presses.

Although cellulose acetate is quite suitable for spectacle frames, it is a fact that when these do break the fracture is quite frequently found to be at the nose-bridge, where the material is subjected to the continual action of moisture, sweat acids and grease, as well as to a certain amount of abrasion. Moisture appears to be the most important factor and it would seem that cellulose acetate butyrate might be more suitable than straight acetate, owing to its extremely low moisture absorption. The latter is only half that of the straight acetate and has practically the same physical properties: the specific gravity is, however, somewhat lower.

In 1938 it was announced that moulded ophthalmic lenses of methyl-methacrylate resin would shortly be made by Combined Optical Industries Ltd. and that these would be available at prices

not exceeding those at present ruling for the " Best Form " glass lenses. It was stated that for the first time in the history of ophthalmic lenses corrections for both spherical and astigmatic aberrations would be available for normal dispensing. Advantages claimed by the manufacturers for their " Plasta " lenses were:

1. Actinic value much higher than that of glass.
2. Will not warp or distort.
3. Fitting to frame can be done without risk of breakage.
4. Practically unbreakable.
5. Light to wear.

So far these moulded lenses have not appeared on the market in any quantity, if at all, but no doubt interesting developments can be expected after the war. It is encouraging to be assured that the plastic lens has a finish equal to the finest glass polish and that the surface hardness will withstand all normal usage. The aim of this pioneer company is to make:

1. Ophthalmic lenses.
2. Simple lenses, including aspherical magnifiers; opera glass oculars and objectives; camera viewfinders and meniscus objectives.
3. Optical flats and prisms.
4. Non-optical flats.

**Advertising Novelties and Office Equipment.**

Before the war a large number of manufacturers were making regular use of plastics for desk blotters, calendars, diaries, novelty cigarette boxes, ash-trays, ink-stands, paper-knives and many other useful items usually found on the business man's desk. Choice of plastics for this purpose was not based entirely on price, indeed, in some cases plastics proved more expensive to use than metal or wood, but because of the novelty of the material, permanent colour effects, light weight and good wearing properties. Moulded advertising novelties are particularly suitable where a large output of some thousands is assured, as this covers the high cost of the tools. Where, however, the estimated requirement is in the region of hundreds, not thousands, then expensive tools are not justified and the use of cast resins or thermo-plastics should

be considered. These can both be fabricated by forming and machining and are particularly suitable for series production.

Since the outbreak of war a good deal of attention has been given to the possibility of using plastics in place of metals in the manufacture of office equipment and it was reported some months ago that both the Home Office and the Office of Works were encouraging manufacturers to develop this new application. There is no doubt that plastics could be used to considerable advantage in the production of such things as typewriters and duplicators, but for the actual furniture of the office, particularly large items like filing cabinets, it would not appear to be readily feasible to make generous use of plastics as steel is more suitable and certainly more economic for the purpose. It does seem a little strange, however, that greater use is not made of plastics for typewriters, as their employment would mean a considerable saving of metal, decrease in weight and greater convenience of handling. The latter factor might well be very important in the case of portable machines. One of the most interesting of recent applications of plastics in the business equipment field is the new American Cardineer rotating card index file, which is now provided with a moulded phenolic motivating wheel. Extruded phenolic resin tubes or cylinders have been in use for duplicating machines for some years now with great success, supplanting the old type of plaster ones. Moulded phenolic cases are also now being fitted to Gestetner and other well-known makes of machines and ensure maximum protection with minimum weight and improved appearance.

**Plastic Dentures.**

During the last few years considerable progress has been made in the use and development of plastics for dental bases in place of vulcanite, which has been in use for well over seventy years. Although vulcanite possesses excellent wearing properties, including reasonable freedom from warpage, its colour stability is unsatisfactory.

There are several different kinds of plastics used in the moulding of denture bases and these include those of cellulose origin, phenol-formaldehyde resin, acrylic resin, mixed acrylic resins and vinyl resin. Good results can be obtained with all these plastics and they have the advantage of combining natural colour effects

and translucency with fair to excellent colour stability. Generally speaking, however, they are not as easy to work by the dental mechanic as vulcanite and for this, as well as other reasons, they do not find the wide application they deserve. It should be noted that the plastic denture bases are usually more expensive than those made of rubber.

The greatest advance in the search for a perfect denture base promises to be made by the adoption of acrylic resins. They possess very good mechanical properties which are even superior to those of vulcanite, cellulose, phenol-formaldehyde and vinyl. Other advantages shared by these comparatively new synthetic resins are: better ageing properties in the presence of oral fluids and when exposed to the air; better resistance to warping influences; lightness in weight, greater comfort in use and increased resistance to bacterial growth. Acrylic resins appear to represent a great advance on the phenol-formaldehyde resins which, although in many ways very serviceable and strong, are liable to warp and tend to become rather brittle after being in use for some months. As various acrylic polymers and mixtures of acrylic and styrene resins may be produced at will, it would, therefore, appear as if the dentist will shortly have available a range of materials of different degrees of hardness and possessing varied physical properties which may be exploited to the best possible advantage.

Mr. W. T. Sweeney, Research Associate of the American Dental Association at the U.S. National Bureau of Standards, has carried out a good deal of work on the acrylic resins for denture bases and his findings are recorded in a paper read before the Full Dental Prosthetic Section of the American Dental Association, July 19th, 1939. The tables opposite summarise the results of Mr. Sweeney's investigations and tests.

Apart from the use of plastics for dental bases, they find applications in the manufacture of high-class surgery equipment. Thus methyl-methacrylate resin, such as Lucite and Perspex, are used for what is now known as "cold light" dental instruments, that is, instruments fabricated from the rod or tube which, when connected with a source of light, have the property of transmitting the light to the business end of the instrument. The light emitted from the acrylic tongue depressor or retractor is not only cold, but free from all glare and yet possessing a high degree of

COMPARISON OF HARDNESS AND PHYSICAL PROPERTIES OF RUBBER AND ACRYLIC RESIN BASE MATERIALS

| Material. | Indentation Hardness. Knoop Method (kg. per mm.²). | Transverse Tests at 37° C. Deflection at Load of | | | Breaking at Load (grm.). | Tensile Strength (kg. per cm.²). |
|---|---|---|---|---|---|---|
| | | 4,000 grm. (mm.). | 5,000 grm. (mm.). | 6,000 grm. (mm.). | | |
| Olive base rubber | 13·4 | 1·68 | 2·77 | 3·64 | 8,000 | 555 |
| Acrylic resin No. 1 | 17·5 | 2·25 | 3·73 | 7·06 | 6,100 | 575 |
| Acrylic resin No. 2 | 20·3 | 2·01 | 2·98 | 4·30 | 7,000 | 685 |
| Acrylic resin No. 3 | 17·6 | 1·79 | 2·72 | 3·91 | 8,000 | 641 |

RÉSUMÉ OF CHANGES IN PLASTIC DENTURES IN SERVICE

| Base Material. | Type of Denture. | Time Service. | Change across Posterior. | Fit on Model. | Colour Change. |
|---|---|---|---|---|---|
| Phenol-formaldehyde resin | Full upper | 1 month | − 0·52 | Satisfactory | None |
| | | 5 months | − 1·04 | ,, (tight) | None (some stain) |
| | | 13 months | − 1·55 | Not satisfactory | Faded and stained |
| Rubber | Full lower | 7 months | − 0·04 | Satisfactory | Stained |
| | | 15 months | − 0·11 | ,, | ,, |
| Acrylic resin No. 3 | Full upper | 1 month | + 0·24 | Satisfactory | None |
| | | 9 months | + 0·59 | ,, | ,, |
| | | 17 months | + 0·51 | ,, | ,, |

luminosity. A complete set of such instruments is now available for dentists in the U.S.A. and according to reliable reports these instruments are proving of the greatest value in serious dental operations. As methyl-methacrylate resin softens in boiling water antiseptics must be used for sterilisation.

Apart from the above very interesting application, which exploits a unique property of methyl-methacrylate resin, the other important uses of plastics in the dental field are confined to small moulded components for X-ray lamps, fittings for dental chairs, etc., usually made of phenol-formaldehyde resin.

**Plastics in the Schools.**

It is encouraging to find that educational authorities are now taking an increasing interest in plastics and in a number of schools

metal and woodworking classes are now fabricating various articles of plastics, particularly cast resin, methyl-methacrylate rod, tube and sheet, cellulose acetate and casein. The growing popularity of plastics is accounted for by the fact that they can be worked fairly easily with standard tools and equipment and that they are available in a large number of attractive colours and, in the case of the acrylic resins, also cast resin and cellulose acetate, in transparent forms. Experiments with the light-conducting properties of methyl-methacrylate tube, rod and sheet have opened up a still wider scope for this plastic, and in one school at least, the writers are aware of a full consciousness of this unusual property and a desire to exploit it in the fabrication of desk-lamps, lamp-shades and various other fittings.

The use of handwork in plastics depends upon the extent of the work carried out and the use which can be made of the experience gained when the boy or girl leaves school. All of the handwork is non-vocational and designed primarily to develop skill in the use of tools. The choice of plastic materials is usually made because it is known that they are exceptionally easy to fabricate and, being still somewhat of a novelty, are therefore more interesting to work with than either wood or metal. Although it is very unlikely that more than 1–2 per cent. of the students taking part in this new branch of handcraft eventually enter the plastics industry, the writers are certain that even a rudimentary knowledge of plastics and how they stand up to fabrication methods will prove of some ultimate benefit if it only increases general knowledge. Probably the greatest benefit to be gained by those taking part in what might be termed plastics handcraft will be shared by those possessing definite artistic ability who have an ambition to train as draughtsmen or designers. Their introduction to plastics in their adolescence may possibly direct them towards the plastics industry and so be responsible for introducing into it fresh blood and new ideas.

Plastics approach very closely to the ideal materials, as they are more adaptable than either wood or metal. Take, for instance, acrylic resin in the form of Perspex. This can be moulded or formed with comparative ease, or it may be cut to shape, etched and carved, drilled and machined as easily as brass or wood, provided certain elementary precautions are taken to ensure that the tools are not overheated during work.

The chief disadvantage or, rather, the main handicap likely to prevent the more generous use of plastics as handcraft materials is their high cost. This may, however, be overcome to a large degree by having an arrangement with suppliers or manufacturers to secure scrap at reasonable prices. Most manufacturers will, in normal times, be found very willing to co-operate with educational authorities and it may be possible to arrange visits to works so that students can actually see the plastics they fabricate being manufactured.

## CHAPTER XVII

# DESIGN

It has been said by more than one critic that design as taught in our modern industrial art schools is divorced from reality and that students are discouraged to question too closely the practicality of designs as definite commercial propositions. We do not propose to heap more coals on the heads of art masters, but we believe that if the truth were known they really do despise industry and loathe to acknowledge or recognise the necessity of designing for mass production. Mass-produced goods are usually considered to be shoddily made and poorly designed, and the very term " mass produced " has almost come to be regarded as the antithesis of well designed and well made.

Although in many ways it is regrettable that the craftsman should be ousted in favour of the machine, there is no use in shutting our eyes to the march of time and refusing to adapt ourselves to the new order of things. This is an age of mass production. It must be so, as in no other way is it possible to feed, house, and clothe the population at the present high standards or even to provide the teeming millions with education or amusement. Whether this is desirable or not is, we fear, another and far more complex question which we have no wish to answer. Mass production, once the necessity for it is accepted, must then be encouraged by all the forces at our command.

The engineer has readily adapted himself to the production of machines to make possible the mass production of a thousand and one things, and the chemist has adapted his knowledge of science to make possible the synthesis of hundreds of new products. In many cases the artist has been more than a little contemptuous of the machine and, whilst regarding it as an unfortunate necessity, shown little desire or even ability to recognise the great opportunity this new age offers to art. The plastics industry particularly calls for the wholehearted co-

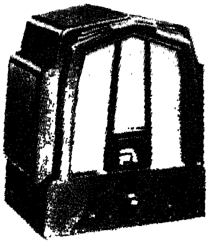
operation of the trained artist, but he must be something more than an artist. The man of greatest value to the moulder is one who is equipped with a sound background of training in an industrial art school, who has served an apprenticeship in an engineering shop, and even, perhaps, spent some time as a salesman so as to obtain an insight into what the customer or client wants. The designer engineer is known in America and his services are being eagerly sought after by progressive manufacturers who realise that he is able to produce a more attractive, functional and, what is far more important, a more saleable article. Whereas in this country the tendency is first to ask how much the services of a good designer will add to the cost of the goods, in America it seems to be rather different. The American moulder appears to ask himself first the question—what can the designer do for me, and secondly, what will he cost me ? We do not wish to infer that the American business man is one whit less anxious about costs than his prototype in Great Britain, but we do consider that he realises that first things come first. The design comes first, the cost second. A good design will lift an article, a product, out of the rut and give it a far greater chance of achieving popularity than any other single factor. A mediocre design, on the other hand, stamps the product as mediocre and is a definite handicap.

In our conception, the engineer designer differs radically from what might be termed the academic designer, because he is essentially practical. He is, also, more cautious in his attitude, less prone to condemn and more inclined to compromise. He knows, for instance, that a successful design is rarely evolved overnight, and that it usually represents a stage in the development of a successful product. Good designs, and by that we mean designs that help to sell goods, must be developed gradually, step by step, and it is only very rarely that they can be produced in one fell swoop. Radical changes, which may be considered too advanced, are frequently dubbed " ahead of their time " and thus fail to achieve success. How often do we hear that a particular model of motor-car or radio was a failure, commercially, because its lines were too stream-lined or its general conception too extravagant,—in other words, it was ahead of its time.

The measuring-stick of the designer's success in industry must be judged solely by the public reaction to the goods he designs.

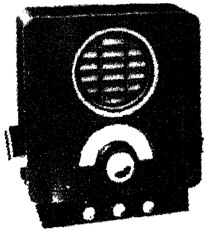
Whilst one may applaud the idea of designing for posterity, in reality it is the immediate present that matters most. It has been proved time and time again that a well-designed article sells for two main reasons: it appeals to the eye and fulfils its purpose with the maximum efficiency, that is, it is functional. This does not mean, of course, that a badly designed article does not sell; on the contrary, many thousands of clumsily shaped articles do sell very well indeed, in spite of their atrocious design, simply because they fulfil a public need. An excellent example of this was the original electric iron. This was a particularly ill-conceived modification of the old flat iron but it sold because people were attracted by the novelty of the idea and the general usefulness of the article. When, however, competition became intense, manufacturers thought about design as a means of making the iron more attractive and therefore more saleable. The designer thereupon set to work to smooth out some of the ugly corners and to "modernise" the shape, knowing full well that design had necessarily to be subservient to function. In his efforts to build up a new and better iron a survey was made of modern materials calculated to improve appearances and also increase the serviceable properties of the iron. In this way the modern stream-lined and yet highly practical electric iron of 1940 was evolved; step by step in accordance with public demands as made evident by the reaction to competitive efforts.

In the field of plastics this gradual development of design is of particular interest because the industry is of such recent date that we can recall the various stages marking its progress. Having passed through the ash-tray and smallware stage to mottled radio cabinets, it has now reached the general industrial phase when plastics must be considered alongside metal, wood and ceramics as standard materials. During those early days of the industry very little attention was paid to the design of the moulding, attention being focussed primarily on the exploitation of the materials themselves because of certain characteristic properties, such as heat-resisting, dielectric lightness and permanent colour effects, etc. Real design consciousness and colour sense came only very gradually and much of the early work was amateurish and heavy handed. That is, of course, only natural when we consider that designs were not evolved by any really logical process of artistic reasoning but "knocked up" by moulder or toolmaker. Need-



1931-3.
Ekco own design.

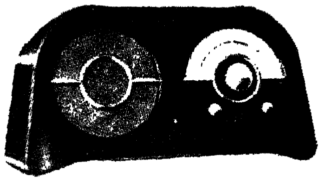
Ekco own design.



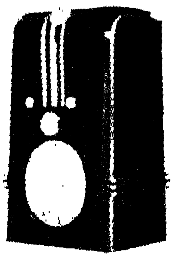
1933-4.
Chermayeff d

1934-5.
Ekco own design.

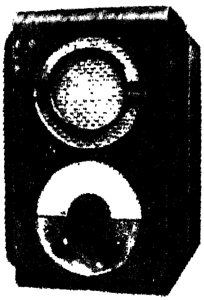
1935-6.
Wells Coates design.



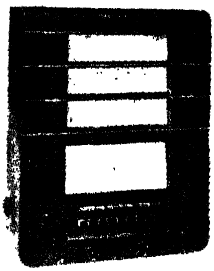
1935-6.
Chermayeff design.



1936-7.
Jesse Collins design.



1937-8.
Mischa Black design.



1939-40.
Ekco own design.

Moulded radio cabinet progress.
E. K. Cole, Ltd., Designs, 1931-40.

[*Facing p.* 228.

less to say neither the moulder nor the toolmaker was qualified to produce clean and simple designs, let alone original ones. The trained designer was practically unknown to most moulders ten years ago, although, of course, the very large concerns thought it worthwhile to utilise occasionally the services of a consultant.

Some of the most outstanding of the early designs are to be found in the radio field. E. K. Cole, for instance, made great use of well-known designers in developing and popularising the first plastic radio sets. Thus in 1933–4 Chermayeff produced two popular designs, in 1935–6 Wells Coates was responsible for an entirely new departure in style and treatment of the moulded cabinet; Jesse Collins brought out an outstanding design in 1936–7, and in 1937–8 Mischa Black's name was associated with a new model. Studying these early models produced by Ekco since 1931 one is immediately struck by the gradual development of the design, from a simple and rather ugly box-shaped cabinet which served its purpose but had no pretensions to beauty, to a moulded cabinet of simple and yet satisfying shape which can be said to be both attractive and functional.

Turning now to the actual work of the designer in the plastics industry it must be emphasised that his scope and opportunities are daily increasing. Not only is the designer at the service of the moulder in developing new ideas or modifying old ones, usually the latter, but he is available either as a consultant or staff man for surveying the whole field of industry and suggesting new uses for plastics. The successful designer must not only be competent in his own art, but armed with a good working knowledge of plastics. This does not mean, of course, that excellent designs are not possible unless the designer thoroughly understands the materials he is dealing with, but it does mean that success is more likely to be attained if he has that knowledge.

It is useful at this stage to consider quite briefly the evolution of the tools used to mould a particular article from the basic idea to the actual dies required to turn out the moulding. In the first place, let us suppose that a manufacturer using metal die castings for the housing of a particular kind of electrical device, say, a home thermostat suitable for controlling small- and medium-sized electric fires, considers the advisability of employing plastics. He may do so for several reasons. To improve the appearance of the thermostat; to increase its safety by reason of its superior insulat-

ing properties or to cut out certain finishing operations necessary in the case of metal die castings, such as sand blasting, spraying and baking, etc. Coupled with these factory reasons may be others which his salesman in touch with the market may put forward, for instance, the pleasant warm feel of the moulded housing and its more permanent colour, etc. Usually, however, the main and compelling reason for a change in materials is price. If plastics work out cheaper than metal or wood, then this is a reason overshadowing all others.

The manufacturer may approach the moulder armed with a rough sketch of the proposed moulding or he may have gone to considerable trouble in obtaining a working drawing of the desired moulding. In any case the sketch or working drawing is used as a basis for discussion between the client and the moulder. As a result of this it is agreed to use a certain type of plastics, in this case urea moulding powder, and to obtain the services of a designer to develop the manufacturer's idea on the best possible lines. Next is discussed the probable size of the order.

At last having settled all these various points the moulder promises to proceed with preliminary stages and to get in touch with a designer. If the moulder considers that the order is an important one, or is likely to develop into a profitable connection, then he may seek the services of a consultant, that is, of course, presuming that he has not a designer on his own staff, in which case the work is put in hand automatically. If, on the other hand, as is very often the case, the moulder has no experienced designer on his own pay-roll, and he is not inclined to pay five, ten or twenty guineas to an outsider, he compromises by asking his toolmaker to work out a design, which he is usually only too pleased to do very cheaply. This course frequently leads to mediocre results, because although the moulder saves some money he cannot hope for an original treatment from an engineer's draughtsman who has neither the breadth of vision nor the experience for this class of creative work. It might also be mentioned that the draughtsman in the service of the toolmaker is bound to find his style and efforts severely cramped by the limitations placed on him by his employer.

Let us now suppose that drawings have been made, it matters little for our purpose by whom. These are then sent to the client for his approval. If they are passed, the next step is the prepara-

tion of working drawings and finally a model in wood, clay or perhaps plastics, such as a cast resin, which can be readily machined.

No doubt modifications will be suggested, perhaps by the designer himself, especially if he is a consultant, the moulder and the client. The designer may, for instance, suggest certain changes in the shape calculated to improve the general appearance or functional properties of the device, or he may consider that the colour might be changed to better advantage. These suggestions or recommendations by the designer are only likely to be put forward if he is a consultant and therefore in the position to put forward independent views, but less likely if he is on the staff of the moulder and still less likely in the case of the toolmaker's designer or draughtsman.

The moulder himself, being a practical man, is mainly concerned with the actual job of moulding the article in the minimum time and with the minimum amount of trouble. Thus his suggestions are calculated to improve flow and to obviate the possibility of certain weaknesses appearing in the finished work. His criticism is, in fact, generally confined to the practicality of the design from the production angle.

The client on the other hand has to consider the model from several different angles :

1. Cost.
2. Service and life of moulding.
3. Sales appeal.

On these important points he seeks the advice of his engineer and sales-manager who are in the position to advise him regarding questions of production costs and the other vital factors, particularly the public reaction to the new housing. He is then able to consider the recommendations, if any, made by the designer and moulder. Once a definite decision is reached, a matter which usually takes some time as the client is torn by so many doubts, either new drawings and new models are prepared, or an order is placed straightaway for the tools.

In approaching the design of an article to be made of plastics, the designer has to keep in mind the fundamental fact that shapes successful in metal are not necessarily successful in the new medium. The mechanical strengths of plastics and metal are

widely different and even the ratios of specific gravity and impact and tensile strengths of the most commonly used plastics do not compare very favourably with metal. In view of this discrepancy in strength the plastics designer must adopt a new method of approach to problems and use devices, such as attachment inserts at filleted corners of boxlike shapes, to strengthen inherently weak shapes and prevent disfiguring flow marks. Stream-lining is more often than not a device calculated to increase strength and facilitate flow and not, as so many people think, a conscious effort to " modernise " a design. The designer is frequently faced with the task of adapting a metal shape to one moulded of plastics and this presents a number of ticklish problems as it is very rare, indeed, that modification can be as simple as the client expects. In general the shape has to be cleaned up by smoothing down sharp corners, using domed shapes instead of flat-topped ones and adding extra thickness wherever strains are likely to be set up. There are, in fact, a hundred do's and don'ts, and to catalogue them would achieve no really useful purpose. The designer may be said to make use of these various devices or tricks to ensure that the moulded article is able to give the maximum service. The great difference between what might be termed an engineer's design and properly trained designer's work is that whereas the former is mainly concerned with function or service and tries to achieve good looks by what might be termed " jazzing up " the shape, the designer proper considers all aspects of the problem as one entity ; cost, function and appearance being regarded as closely inter-related.

The problem of colour and shape is of the utmost importance and this is where the services of a properly trained designer are likely to be of great value. Unhappy choice of colour can, and indeed, has, caused the failure of many otherwise quite promising ideas. Take, for instance, the coloured radio sets produced as a market feeler in 1938. Some of these were moulded in very cold stone-coloured urea material which unfortunately gave the cabinet a very heavy and massive appearance intensified by the tall and fluted shape. Thus one had the impression, strange as it may seem when one seeks to analyse it, that the cabinets were carved out of solid marble and that if placed on a mantelpiece or bookcase they would crush it with their weight. As stated above, this strange impression of coldness and over-bearing weight was

largely intensified by the tall shape of the cabinet. A squat shape would not have given this impression to the same extent and maybe it might have succeeded even in spite of a cold, stone or marble-like colour.

In the opinion of the writers the designer should be wary of using shapes which tend to exaggerate the effect of weight, massiveness and solidity. He can only do so if he is something of a psychologist as well as a practical designer. He must be well able to analyse the reason why Mrs. Brown prefers one shape or one colour to another and why some colours only suit certain markets. This naturally calls for a certain amount of market research. This usually reveals that for what might well be termed the high-price market, the pastel and delicate tints are suitable, but for working- and middle-class markets their choice would be very hazardous. Referring back to radio cabinets, if these are intended for the working-class market they must tone in with the dark oak and heavy colouring usually found in the average living-room of the £3- to £5-a-week man. To suppose that an ivory or pink cabinet would blend in with the above is surely to be rather foolishly optimistic and divorced from reality. The argument applies equally well to electric fires, and one well-known manufacturer who produced a range of small moulded bedroom fires in white, black and red found it extremely difficult to dispose of any red fires. The dislike to appear too conspicuous is, unfortunately, still very deeply ingrained in the average working- and middle-class family. In America things seem rather different as both working and middle classes are not afraid of colour and the manufacturer must, if he wishes to retain the market, ring the changes on both colour and shape with every new model he produces.

Whilst on this very controversial subject of colour and shape it is important to remember that a design which may prove quite successful in dark phenolics may not give equal satisfaction when the moulder switches over to urea. These two types of thermosetting moulding powders do not possess identical flow characteristics and this difference may cause some trouble and be responsible for the appearance of weak parts in the urea moulding.

It is encouraging to find that the need for the services of a trained designer is becoming more widely felt throughout the entire industry and efforts are now being made to satisfy the

requirements of the moulder by such schemes as the Kenneth Chance Scholarship. This is open to art designers employed in any branch of the plastics industry and enables the successful applicant to spend a further year in the study of art as applied to the production of factory-made wares. The funds are provided by British Industrial Plastics Ltd., while the award and general administration of the scholarship are in the hands of the Institute of the Plastics Industry Ltd. One scholarship is available annually of the value of £150 and is tenable at a school of art selected by the scholar and approved by the Institute. In addition to this, excellent work is being done at the Reimann School and the Central School of Arts and Crafts, as well as several other centres. In the prospectus dealing with a special industrial design course at the Central School of Arts and Crafts given by Mr. Mischa Black in 1940, it was stated that particular stress was being placed on the design of those articles of everyday use which are mass produced. The normal three-year full-time course at the Central School is intended for students who intend to work as staff designers in the larger light industries, such as plastics, cars, or domestic appliances ; or those who operate as consulting designers on a wider scope.

It has been suggested that what is really needed to-day by the plastics industry is a central bureau of designers properly trained and thoroughly well fitted to deal with all types of commissions and problems concerning plastics. This idea will not, we feel sure, be acceptable to the small moulder who, although quite aware of its possible advantages, cannot afford, or thinks he cannot afford, any design cost whatsoever. As stated earlier in this chapter, his normal process, if he has no designer, is to approach his mould-maker who is usually completely devoid of any real artistic ability and is only capable of turning out an engineering job. When the moulder attains his object by getting the toolmaker to adapt an existing design he is under the impression that he does not pay for it as his invoice usually makes no mention of this service. This is, of course, a gross error as the time spent on the work by the toolmaker's draughtsman is added on to the total cost of the tools.

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